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CEO to the Rescue: Residential Proximity of Private Firm CEOs and the Evolution of Corporate Profitability

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This paper documents how the net profit margin of private firms improves when the CEOs of the companies relocate their primary residence to be closer to the corporate headquarters. By reviewing 127 Korean non-public companies belonging to 66 private business groups, we find that the top managers move closer to the headquarters when the profitability of the firms has recently deteriorated. A one basis point decline in the margin causes CEOs to relocate their homes approximately two kilometers closer to their corporate headquarters. The profit margin rebounds after their relocation. This finding implies that physical proximity can serve as a proxy for personal commitment.

Key Word: CEO, Corporate Governance, Geographic, Commitment
JEL Code: G30, G34, G39

I. Introduction

Chief executive officers (CEOs) are individuals who make critical decisions regarding their corporations. Therefore, their level of commitment is essential for their businesses to flourish. However, the current literature rarely touches upon the issue of how to measure the level of CEO commitment. Most studies dealing with the link between CEOs' efforts and firm performance assume that CEOs are best incentivized when their personal net incomes are maximized.[1] However, the literature seldom provides any specific channel by which CEOs commit to their business. In this paper, we examine how close CEOs' residential homes are to their corporate headquarters as a proxy for their level of commitment and study how different levels of the commitment are related to the profitability of their firms.

There are several reasons that make it more than a simple and random choice for

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[1]See Brown *et al.* (2007) and Bergstresser and Philippon (2006), among others.

CEOs when they decide where to live. First, residential relocation is not an easy decision considering the time and expenses required when searching for a desirable residence and considering factors such as school transfers for children. Therefore, once CEOs choose a certain region, it is highly likely that they will stay for a while, trying to remain at ease in the location as long as they can. As residential relocation is such a difficult decision, it represents significant determination of any type once made by a CEO. Second, CEOs can choose a residential area without rigid budget constraints and can also afford long commutes in general compared to low-ranked employees. Unlike most low-ranked employees, CEOs may have far fewer financial restrictions with regard to selecting where to live, and they may have a wider range of options when choosing a residential area. CEOs can also more flexibly decide when they should appear in their offices. In other words, they have more discretion in adjusting their schedules such that that they do not need to come to their offices at a fixed time on a daily basis. This sort of flexibility makes CEOs more able to endure a long commute, as they can manage most of their official duties and minimize losses of their personal time during business hours, and compensate for the long commute accordingly. Under circumstances which allow wider options with regard to their residence, when CEOs relocate closer to corporate headquarters, it distinguishes them as individuals willing to pay more attention to daily business operations.

To study the link between CEO residential proximity and firm performance, a specific group of companies was deliberately selected to best fit our research purpose. The group covers pairs (or 'trines') of Korean private companies, both (or all) of which are managed by a single CEO. There are several reasons behind the selection of this sample set.

First, large listed firms do not serve our research purposes well, as the daily business operations of these types of firms are mostly conducted by a group of professional managers who are well equipped with their own specialties. Under such an environment, a different commitment level of a single CEO does not have a critical impact on the firm's profitability, as more of critical decisions are not made by the single CEO but by a group of professional managers compared to a private company, where a single CEO maintains more dominant leadership. Equivalently, for large listed firms, the CEO's residential proximity to corporate headquarters becomes less relevant to their level of commitment because, for listed firms, it is not a single person but a management system that manages most daily business operations. The management system inside large listed firms is well supported by state-of-the-art business intelligence software which gathers and analyzes massive amounts of information efficiently, providing timely reports to assist with critical decisions. This type of systemic approach to the general management of large listed firms makes the CEO's geographical commitment less influential over how well the firm is managed.

Second, we study and compare only pairs (or trines) of companies controlled by the same CEO for the following reasons. Suppose that we find that a firm's profitability deteriorates when the CEO of the firm relocates his/her home further from the firm's headquarters. Such a finding establishes a false causality if we naively interpret it as evidence that the CEO's relocation to a more remote region reflects a reduced level of commitment and, therefore, compromises profitability.

In fact, the decision to relocate farther away may not be an indication of a lower level of commitment but merely a simple move to provide a better schooling environment for the children of the CEO. As a partial remedy, we opt to trace changes in the CEO's residential proximity and firm profitability after controlling for CEO-fixed effects that may be embedded within each private business group. Despite the possibility of a CEO living away (closer) from (to) the corporate headquarters for unrevealed personal reasons, it reduces the chance to establish false causality when we study the values of residential proximity between a pair or trines of companies under the same CEO's supervision. Therefore, if we can find any systemic evidence showing that changes in commuting distance are related to differences in profitability in the firms controlled by identical CEOs, the evidence becomes less vulnerable to the potential criticism of spurious causation.

Third, the Korean regulatory system provides unique data, such as annual financial data for private companies and the history of the CEO's residential addresses. This informational advantage makes a study of this type feasible in Korea, as it would be unachievable in other countries. Korea is a country where business groups are prevalent even among private companies and where a public financial data warehouse ("DART") reliably provides financial statements from private companies, as long as the size of the company exceeds a certain threshold.[2] This unique environment indicates that Korea is a good place to analyze pairs of private firms under the control of the same CEO.

Fourth, without exception, the CEOs studied in this paper are all controlling shareholders of our sample firms. This phenomenon prevails, as relatively small-sized family businesses can seldom afford high-quality professional managers and/or the owner-managers are presumably most dedicated to the specific fields in which they spot new business opportunities. The individuals exert themselves to promote opportunities to build their family business empires. This unique environment, specifically the perfect match between CEOs' private incentives and the prosperity of their family businesses, makes research on their level of commitment more reliable than a study of professional managers whose personal incentives are often not best aligned with those of the firms for which they work.

Lastly, the home addresses of CEOs managing private companies are obviously private information and are not obtainable from public sources in general. This characteristic of the information has thus far made geographical analyses of private companies challenging. Fortunately enough, the Korean Supreme Court runs a public corporate registration system (www.iros.go.kr) where various bodies of corporate information are disclosed to the public when there is any change for such information. Although the system does not offer data in a fully automated manner, it still allows any individual to examine the business information of any company, as long as the individual pays a certain processing fee and is willing to endure the laborious task in flipping through corporate profiles in the system. The corporate information includes the history of CEO turnover, the CEO's residential addresses, the total amount of equity issued or to be issued, debt issuance, and other pertinent

[2]DART stands for Data Analysis, Retrieval and Transfer, which is a data warehouse managed by the Korean Financial Supervisory Service ("FSS"). A private company in Korea is required to report audited financial statements to DART, once the company's total asset exceeds KRW 10 billion, equivalent of USD 10 million.

information. By seeking this type of corporate information in the registration system, we construct a dataset of how each private company CEO's home address changes over time. This unique data enables us to study how geographic factors at the individual level affect firm-level performance among private companies.

Several questions are proposed regarding the relationship between a CEO's residential proximity and their firm's accounting performance. How does a firm's profitability change as the CEO moves their home further away (closer) from (to) the corporate headquarters? How does year-over-year profitability of a given firm evolve before and after the CEO relocates their residence? What motivates a CEO to move closer to their corporate headquarters?

The overall empirical findings of this paper indicate that the CEO's residential proximity and the firm's accounting performance are positively correlated after controlling for CEO-fixed effects and industry-specific factors. Private firms' accounting performances improve when the CEOs of the firms move their residences closer to the corporate headquarters. When we look into year-over-year progress on net profitability within each private company, the profit margin in excess of the industry average is found to grow when the CEO's residential home is closer to their corporate headquarters. A test of average profitability before and after the CEOs' relocation closer to the firm reveals that, on average, the net profit margin is weaker before the relocation than it is after the CEOs move closer. An investigation of the ten-year progress of net profitability across such relocations also confirms that the net profit margin consistently declines during the four years before the CEOs' residential move closer to the head offices whereas the margin improves in the long run after their relocation. Combining the findings above, we show that the CEOs of private firms commit themselves to their businesses by relocating closer to the firms once they find persistent and serious declines in corporate profitability and that such commitment rewards the CEOs given the revitalization of the profitability in the long run.

Existing literature proposes a possible mechanism to explain how individual-level commitment enhances corporate profitability. Porter (1996) argues that "dedicated positioning" is critical to earning and maintaining excessive profits, and finds that profitable companies are more likely to implement one of the following positioning strategies: releasing differentiated products, offering a competitive edge on cost management, or a combination of the two. The author stresses that such competitive positioning becomes viable only with the serious dedication of related stakeholders. Allen and Meyer (1990) conceptualize under what circumstances individuals commit themselves to their work. The authors argue that individuals show high levels of dedication when they are emotionally attached to the workplaces ("affective commitment"), when they have fewer alternative career options outside their current job ("continuance commitment"), and/or when they regard loyalty toward their current employers as a sort of "norm" and feel obligated to stay with them ("normative commitment"). Lee and Miller (1999) found that employee commitment is positively correlated with corporate profitability and argue that dedication in employees makes an organization more profitable.

The CEOs investigated here are unique in the sense that they are capitalists whose incomes are mostly generated from individual instances of capital investment. However, at the same time they maintain their status as corporate

employees, being paid for their labor for the organization. With the existing framework presented by Allen and Meyer (1990) applied, top executives become eligible candidates for testing the effects of an alleviated level of professional commitment on firm profitability. The companies investigated in this study were either founded by the CEOs themselves or inherited from their parents. Due to the nature of family heritage, the CEOs have a solid reason to be affectionate about the business empire nurtured by their family successfully, going through countless hardships ("affective commitment"). Shouldering the family legacy, the CEOs grow accustomed to the loyalty to their family business as a norm to abide by ("normative commitment"). Moreover, as most of their personal wealth heavily relies on the success of the business, the controlling individuals of private firms have a serious incentive to commit themselves to the businesses. Once the family business goes under, the individuals' career options outside the firms are limited, as they have spent most of their professional careers within their family circles ("continuance commitment"). The unique characteristics of the CEOs of private firms make them most likely to be committed to the firm and enable us to test how their individual levels of commitment influence the profitability of their companies.

However, measurements of professional commitment tend to be subjective and remain difficult to quantify. This paper contributes to the related literature by presenting one possible measurement of the commitment level which is more objective and more appropriate for quantifying the depth of dedication. The study uses private firm CEO residential proximity to gauge the level of commitment and reports that a corporation becomes more profitable when the CEO move closer to the firm. Additional empirical tests reveal that CEOs relocate their residences closer to corporate headquarters when the firms recently record poor performance. With their CEOs moving closer, firm profitability gradually improves in the long run. As proposed by Porter (1996), such personal dedication enables the CEOs to manage costs more intensely and to innovate with current products, both of which lead to higher profitability. While a previous study (Lee and Miller 1999) reports a positive correlation between employee commitment and corporate profitability, this paper differentiates itself from earlier studies by presenting a concrete method with which to quantify personal dedication. Lee and Miller (1999) use questionnaire surveys to measure individual commitment, a method often vulnerable to the possible criticisms of biased sample selection and dishonest responses. In contrast, our paper measures professional commitment in a more objective manner, i.e., the commuting distance of top executives, and quantifies the impact of their commitment on corporate profitability. Our results suggest that the CEOs of private Korean companies move approximately two kilometers closer to their corporate headquarters in response to a one basis point decline in the net profit margin.

This paper contributes to the body of work in interdisciplinary geographic and corporate finance fields by initially arguing that physical proximity serves as a good proxy for personal commitment, especially when (1) a person's success (or wealth) is best aligned with the business for which they work; (2) the individual is determined to be devoted to the business, but (3) the prosperity of the business is in peril. We report that the individual reveals his/her commitment to the business by relocating his/her residence closer to the business so that he/she may handle daily operations better, especially when the profitability of the enterprise substantially

drops. The effort to turn the enterprise around requires additional years to see the business eventually revive.

Previous studies interpret proximity as an intermediary of information sharing or networking opportunities. On the other hand, this paper conceives of proximity by presenting the new possibility that physical adjacency means another aspect, that is, personal commitment, rather than concepts already proposed in the literature. Within the new frame, proximity is not an intermediary by which information or social bonds are shared but an outcome which is realized by an individual's effort and dedication.

The remaining part of this paper proceeds as follows: Section II reviews the current literature related to geographic topics within the financial economics context, while Section III shows the empirical results of tests on the questions raised above. Section IV concludes the paper with brief comments on its limitations.

II. Literature Review

One of the most celebrated topics linking local factors in the finance literature is how location affects stock returns. Coval and Moskowitz (2001) report portfolio managers' excess returns as earned by nearby investments. Mutual fund managers are found to invest more in firms located closer to pertinent individuals, as managers are in a better position to investigate firms located closer to them and to gain the upper hand when attempting to possess the timely and accurate information necessary for successful investment decisions. In consequence, the investment professionals gain superior returns from the decisions with the benefit of regional proximity. Malloy (2005) finds that an analyst covering firms in close proximity provides more accurate forecasts. The research on equity analysts is in line with the previous findings on mutual funds (Coval and Moskowitz 2001) in the sense that regional proximity provides an informational advantage.

In addition to the informational advantage of investment professionals, Pirinsky and Wang (2006) document that co-movements of the stock returns are stronger when their headquarters are located in close proximity. The authors find stronger co-movements when the stocks are traded more by less experienced individual investors who are not as equipped with sophisticated financial knowledge and who rely more on regional information resources. Such co-movements, the authors argue, reflect the fact that a geographic element plays an important role in pricing equities. Zhu (2002) proposes a different perspective to explain why individual investors are overweight on nearby companies when constructing their stock portfolios. Their perspective indicates that individuals buy more regional stocks not because they are savvier in their understanding of local businesses but rather because they are more familiar with the enterprises and, therefore, become more agile at responding to pricing-moving corporate issues. Grinblatt and Keloharju (2001) expand the subject, linking regional factors to investors' stock-picking behaviors in an international study. Using Finnish individual-level data, they report that individual investors trade more on companies located closer to their homes.

Korniotis and Kumar (2013) also argue that state-level economic variables

predict the returns of stocks of which the headquarters are located in the same state. One of these authors' contributions to geographic studies within the body of financial literature is an extension of the co-movement phenomenon captured among closely located companies in a nationwide context. The paper also presents a possible rationale behind this type of co-movement, holding that the equity performances of companies in the same region are affected by common economic factors.

For individual-level studies, Hong *et al.* (2004) show that stock market participation is affected by social interactions. They point out that people who more actively interact with neighbors tend to invest more in equity markets, interpreting this finding as evidence that an individual feels more attached to markets of which their friends are a part (see also Brown *et al.* 2005).

Froot *et al.* (1999) present more direct evidence supporting the contention that regional components are priced into equity valuation. They compare the stock returns of companies of which shares are simultaneously listed on multiple stock exchanges around the globe. The rationale of their empirical test design is that stocks should show identical returns as long as the underlying businesses are identical. However, they found that the returns of stocks traded on multiple exchanges deviate from each other. The only difference among these stocks is that they are listed in different locations. With this evidence, the authors elect region-specific factors to explain the deviations.

Hong *et al.* (2005) test how social interactions among investment professionals influence their stock-picking behavior and report that mutual fund managers living in same local community show similar patterns in their portfolio selections. In the paper, they also find that fund managers whose workplaces are located in different regions still show similar stock-picking patterns as long as the individuals reside in the same area. The paper concludes that living in the same region has as much of an impact as working in the same region in establishing social bonds and in sharing common views.

On a different note, recent studies well recognize the importance of the impact of geographic factors on corporate behavior. More recently, Dougal *et al.* (2015) find that a firm's investment is significantly related to the investments of other companies of which the headquarters are in close proximity to the firm. The paper argues that the co-movements of the capital investments are found even among companies coming from different industries, as long as the firms locate their headquarters in the same region. The authors interpret this as evidence that locally clustered economies play a role in determining the level of corporate investment. One possible channel by which regional factors affect corporate behavior was also recently reported (Gan 2007). She contends that Japanese companies use their real estate properties as collateral to back new capital expenditures. As the price of the asset class is highly sensitive to the regional economy, a crash of the real estate market deters firms from executing new investments, possibly due to the lack of sufficient collateral to support the new projects. In a similar vein, Chaney *et al.* (2012) claim that the appraised value of real estate properties has a positive impact on corporate investment when the properties are used as collateral to finance new projects.

Another stream of studies focuses on what factors influence companies when

they choose the venues for their corporate headquarters. Carlton (1983) points out that regional labor costs, energy prices, taxes and municipal incentive programs, and regional technical advantages are the determinants, while an excellent airport system and the clustering of firms within same industries are also important considerations (Strauss-Kahn *et al.* 2009). Start-ups are less likely to bloom in states with higher tax rates (Papke 1991). Garcia-Mila *et al.* (2002) note that local governments, securing their tax base, provide tax incentives to firms willing to relocate headquarters to their municipalities.

Aksoy and Marshall (1992) study how corporate restructuring affects the local economies. As the restructuring effort cuts employment and causes firms to be more dependent on outsourcing, local economies become less vibrant. Davis and Henderson (2008) divide factors determining the location of the corporate headquarters into elements beneficial to manufacturing aspects and elements influencing the sales side. Henderson and Ono (2008) argue that there exists a trade-off between locating the head office closer to a metropolitan area and positioning the office close to production facilities. The authors maintain that headquarters in an urban location make it easier to contract out to support sales activities, while the location choice requires firms to exert more effort in managing production activities that occur far from the firms' headquarters.

Duranton *et al.* (2001, 2005) argue that the regional advantage of locating the head office in an urban area changes from sector specification to a functional specification. Ghosh *et al.* (1995) find that relocating the corporate headquarters induces subsequent stock price movements. The authors report empirical evidence showing that stock markets undergo a positive reaction to the relocation of corporate headquarters when the relocation is related to cost reductions.

For studies dealing with other geographical issues within the corporate finance context, Uysal *et al.* (2008) find that companies acquiring target firms located in nearby regions record higher returns than companies buying entities located farther away. Jaffe *et al.* (1993) study the spillover effect of new patents within nearby regional areas and find that a patent issued by an entity is more likely to be cited by companies located in the same state. Using European data, Orpurt (2004) finds that analysts more familiar with specific regions are better at forecasting the performance of companies active in those regions.

Although previous papers suitably provide firm-level analyses of the relationship between the locations of firms and how they affect corporate behavior, how geographic factors at the individual level affect corporate behavior is rarely touched upon within the corporate finance context. This paper provides new insight into the individual-level analysis of the geographic influence on corporate behavior by studying how the CEO's residential proximity is related to the profitability of their companies.

As noted earlier, the existing literature mostly views geographical proximity as an intermediary through which economic agents share knowledge, build social networks, and achieve early access to location-specific information. This paper differentiates itself from the literature in the sense that proximity is not merely a transmitter by which nearby knowledge spreads or economic agents gain informational advantages on region-specific factors. In contrast, we argue that proximity can occasionally be a result of personal commitment, a *status quo* made

by corporate CEOs exerting themselves to revitalize their businesses after a downturn.

III. Empirical Results

A. *Sample Selection and Data Construction*

To be qualified as a sample firm for our analysis, a firm needs to be incorporated in Korea, privately held, and have sibling firms managed by the same CEO. As our main research question is how the CEO's residential proximity to their firm is linked to the firm's profitability, pairs (or trines) of private firms affiliated within the same business group become ideal candidates for the reasons explained in section I.

Out of approximately 20,000 private firms incorporated in Korea whose externally-audited accounting information is available, we identify 1,717 firms that are classified as affiliates of private business groups. Out of the 1,717 firms, we finally carve out 127 sample firms controlled by 66 CEOs. We define a private business group as a family of private firms controlled by the same controlling shareholders. Records of the shareholding of the CEOs of the sample firms tell that all of the CEOs of our sample firms are also controlling shareholders of the companies.

We download the financial data of the private firms from KIS-Value, a Korean electronic data provider which collects financial information for both listed and private companies. Private companies in Korea are required to report audited financial statements to DART once the company's total assets exceed KRW 10 billion, equivalent of USD 10 million. Financial data providers such as KIS-Value collect and rearrange the contents from the financial statements for public use. In most cases, the footnotes of private companies' financial statements also contain ownership data at the end of each fiscal year. While unlisted companies are not obligated to report their ownership structures, most firms voluntarily report such information. Information on shareholdings is collected manually from the financial statements to be used as control variables in various empirical analyses conducted in this paper.

In addition, we gather time-series address information of CEO residences and the headquarters of their firms and calculate the distance between the CEO residence and the head office. We trace changes in headquarters' addresses from annual audit reports, while assembling CEOs' residential posts from each firm's corporate registration records. As noted above, the Korean Supreme Court runs a public corporate registration system (www.iros.go.kr) which discloses a variety of information whenever there is any change. It also shows when CEOs' residential addresses change. Using a virtual navigation service provided by a domestic portal site (map.naver.com), we measure the distance from the residence to the headquarters. We then record the changes in the distance between the CEOs' residences and their firms' headquarters every year.

Even the shortest commuting route can take many hours if the route traverses

congested areas. In such a case, measuring the driving distance does not serve well as a proxy for commitment. The virtual navigator used to measure distance presents multiple routes when asked to provide possible driving routes from one location to another. The service provider not only provides the path with the shortest distance but also that with the shortest driving time reflecting traffic conditions. For empirical tests in this paper, the route allowing the shortest commuting distance is chosen for calculating the distance only if the route allows the shortest driving time as well.

B. *Main Findings*

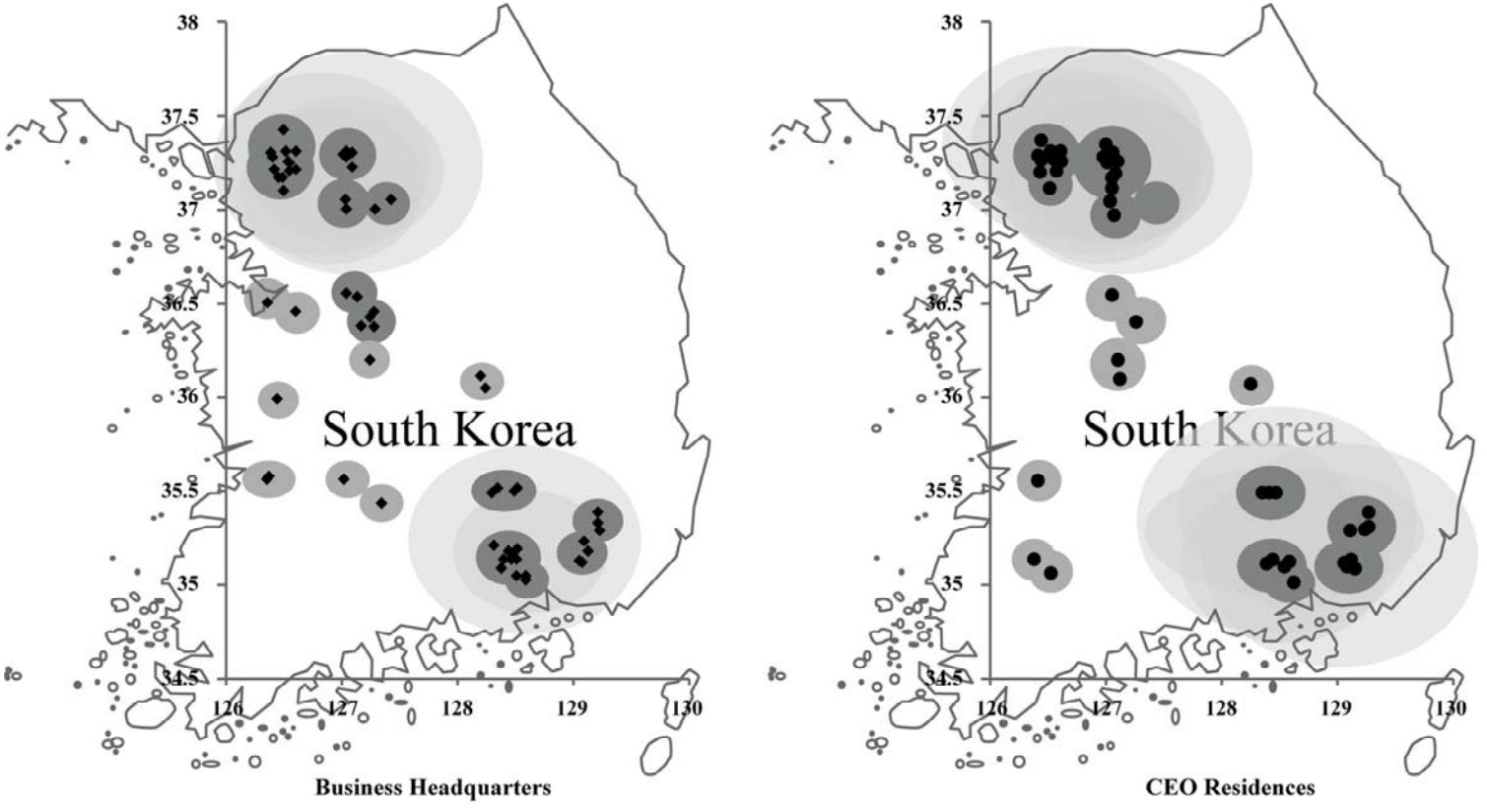
Our basic empirical test strategy is initially to identify the relationship between the *level* of the CEO's residential proximity and the *level* of accounting performance of the firms under the CEO's control. Next, we investigate whether *changes* in proximity are related to *changes* in corporate profitability over time within each sample firm. We implement the two tests, respectively, and confirm that both the *level* and *changes* of residential proximity are positively correlated with accounting performance, even after controlling for CEO- and industry-fixed effects.

Table 1 summarizes the distances from the CEOs' residences to the pairs of firms

TABLE 1—SUMMARY STATISTICS

This table displays information about the geographical distances between the sample firms' headquarters and their chief executive officers' residences, along with various characteristics of the firms. Panel A shows the distance data and accounting information as of the end of 2014. All distances are in kilometers. "Distance: CEO residence vs. HQ" is the shortest road length between the two locations, automatically calculated by a Korean local geographic information provider (map.naver.com). "Distance: HQ vs. HQ" is the shortest road length between two firms' headquarters under the condition that the two firms are controlled by the same CEO. Panel B presents the time-series variation of "Distance: CEO residence vs. HQ." All accounting information is on an annual basis. Bil KRW stands for Korean won in billions. For reference, one Korean billion won is approximately equal to one million US dollars. Total number of sample firms and CEOs are 127 and 66, respectively.

Panel A: Sample Firms' Characteristics (as of 2014)					
Variables	N	Mean	SD	Min	Max
Distance (km): CEO residence vs. HQ	103	62.02	93.09	0.00	388.54
Distance (km): HQ vs. HQ	64	102.90	118.25	0.00	464.00
Foundation Year	127	1992	9.17	1969	2007
Total Asset (Bil KRW)	127	44.97	33.92	10.65	204.00
Total Sales (Bil KRW)	127	48.40	36.74	2.35	173.00
Return on Equity (%)	127	4.83	6.70	-24.06	23.01
Gross Margin (%)	127	17.80	15.73	-29.69	76.57
Operating Margin (%)	127	3.85	7.98	-34.23	20.64
Net Income Margin (%)	127	2.97	8.72	-40.50	34.32
Panel B: Time-series of CEO Residential Proximity to the Corporate Headquarters					
Fiscal Year	N	Mean	SD	Min	Max
2010	90	53.20	78.34	1.53	359.18
2011	97	57.01	84.24	0.83	385.44
2012	101	59.47	88.09	0.00	385.44
2013	105	61.89	92.30	0.00	388.54
2014	103	62.02	93.09	0.00	388.54



This figure is a visual image of the geographic locations of 103 Korean private firms managed by CEOs who control at least two private firms as of the end of 2014. Numbers on the X-axis are the longitude, while those on the Y-axis express the latitude.

FIGURE 1. DISTRIBUTION OF CEOS RESIDENCE AND FIRMS UNDER THEIR CONTROL (AS OF THE END OF 2014)

controlled by each CEO. South Korea is roughly 500 kilometers long from north to south and major industrial complexes are concentrated around Seoul and Busan, the centers of the northern and southern economies. As shown in the table, the average distance between the CEO residence and the firms under their control is 62 kilometers, approximately 40 minutes when driving. By examining distances between the residence and companies which exceed 400 kilometers, we also find that a few CEOs live at one end of the country while managing companies located at the other. Figure 1 visualizes where CEOs lived and worked between 2010 and 2014.

Most of our sample firms are located in one of the two major industrial complexes, one around Seoul (northwest) and the other close to the city of Busan (southeast), while the location distribution of CEO residences is more widely spread outside the industrial complex areas. The fact that the locations of corporate headquarters are not always within reasonable driving distances from the CEOs' residences, as shown in Figure 1, implies that CEOs managing multiple private companies sometimes live far from their corporate headquarters and potentially show different commitment levels with regard to the daily operation of the companies. Measurement of the commuting distance as a proxy for the level of commitment means that the distance measured should reflect how much easier it becomes to undertake daily business operations once the distance is shortened. Therefore, we measure the distance not from a direct linear perspective but according to the driving distance, as the driving distance becomes a better proxy for the CEO's commitment to their business and, therefore, makes the actual driving distance a better measurement of commitment. Panel B in the table displays relatively minor mean variation across the years, implying that relocations of CEO residences or corporate headquarters do not occur frequently. The fact that CEOs do not move often also supports the contention that individuals' decisions to relocate their residences are not easy and, therefore, such relocations aptly deserve attention. From an econometric perspective, the fact that the distance between the CEO residence and corporate headquarters is not volatile over time creates a severe autocorrelation among the distance variable year over year. As a result, clustered standard errors of any regression analysis using the distance variable become inflated, weakening the power of such an analysis.

In Table 2, we regress the level of profitability of the sample firms on variables that may affect the profitability for each company.[3] The key variable of interest is the level of the CEO's residential proximity to their corporate headquarters. In the regression, we control for size, leverage, and whether or not a given company is located in an industrial complex as designated by the Korea Industrial Complex Corporation, along with equity shareholdings of the company possessed by its CEO. As some CEOs are genuinely more capable of managing companies or companies in specific industries yield higher profit margins, we run regressions

[3]The CEOs of private firms may relocate their residences due to the reasons other than the level of their professional commitment. If a CEO's residential relocation is decided upon for educational or lifestyle reasons, this type of relocation is highly likely to bring them closer to either a metropolitan area or a high-end residential district. We find only six occasions of a change in address implying such advantages. For the empirical analyses in this paper, regressions are re-run after excluding the six cases. We find no significant changes in outcomes from the supplementary tests.

TABLE 2—LEVEL OF DISTANCE (CEO RESIDENCE VS. CORPORATE HQ) AND ACCOUNTING PERFORMANCE

This table displays the results of multivariate regressions where the dependent variables are accounting profitability measures. Fixed effects are controlled for identical business groups and industries. The four-digit and five-digit Korean Standard Industrial Classification Code ("KSIC") specifications apply to the industry allocation for each sample firm. Explanatory variables include the distance between the CEO residence and the corporate headquarters ("HQ") under his/her control at a given year. Growth in total assets (%) means year-over-year changes in total assets. CEO's shareholding represents the percentage of equity shareholding that each CEO possesses for the companies under the individual's control. The industry complex dummy equals one if the corporate headquarters are in an industrial complex. Whether a certain HQ is located in an industrial complex is determined based upon a guidebook released by the Korea Industrial Complex Corporation (www.kicox.or.kr/home/facility/sevice_link01.jsp). Free cash flow from financial activities denotes the net cash inflow from financing activities and directly comes from corporate cash flow statements. Cash flow from investment activities denotes net cash inflow from corporate actions related to capital expenditures and comes from the cash flow statements issued as a part of the financial statements externally audited and reported to DART (Data Analysis, Retrieval and Transfer), which is a data warehouse managed by the Korean Financial Supervisory Service ("FSS"). FCFF stands for free cash flow for the firm and refers to the net cash inflow during each fiscal year. Foundation year denotes the year when each sample firm was founded. Numbers in parentheses are t-values. ***, **, and * represent the 1%, 5%, and 10% significance levels, respectively.

Panel A: KSIC Four-digit Industry Classification			
Dependent Variable (%):	OP Margin	NP Margin	ROE
Distance (100km) (CEO residence vs. HQ)	-0.046*	-0.047*	-0.050*
	(-1.86)	(-1.72)	(-1.77)
Changes in capital investment (x10)	0.544	0.544	0.048
	(0.37)	(0.34)	(0.29)
Debt-to-equity ratio	-0.135***	-0.214***	-0.116***
	(-5.45)	(-7.88)	(-4.22)
CEO's shareholding	-0.001	-0.001	-0.206
	(-0.74)	(-0.72)	(-0.95)
Industrial complex dummy	-0.006	-0.012	-0.211
	(-0.41)	(-0.69)	(-0.12)
Total assets (Mil KRW)	0.352*	0.013	-0.033
	(1.88)	(0.06)	(-1.60)
Growth in total assets (%)	-0.419	-0.354	-0.021
	(0.24)	(0.36)	(-0.52)
Sales growth (%)	-0.458*	-0.953***	-0.057**
	(-1.79)	(-3.41)	(-2.36)
Free cash flow from financial activities/FCFF	0.000	0.000	0.000
	(1.06)	(1.68)	(-0.23)
Free cash flow from investment activities/FCFF	-0.010	-0.009	-0.008
	(-0.81)	(-0.66)	(-0.59)
Foundation year	-0.012	-0.070	-0.010
	(-0.08)	(-0.45)	(-0.64)
Business group (CEO) fixed effect	Y	Y	Y
Industry fixed effect (four-digit)	Y	Y	Y
R^2	30.0%	31.2%	36.2%
N	535	535	562

TABLE 2—LEVEL OF DISTANCE (CEO RESIDENCE VS. CORPORATE HQ) AND ACCOUNTING PERFORMANCE (*CONTINUED*)

Panel B: KSIC Five-digit Industry Classification			
Dependent Variable (%):	OP Margin	NP Margin	ROE
Distance (100km) (CEO residence vs. HQ)	-0.046*	-0.047*	-0.050*
	(-1.86)	(-1.71)	(-1.77)
Changes in capital investment (x10)	0.549	0.524	0.047
	(0.38)	(0.33)	(0.29)
Debt-to-equity ratio	-0.134***	-0.217***	-0.116***
	(-5.36)	(-7.90)	(-4.19)
CEO's shareholding	-0.001	-0.002	-0.207
	(-0.74)	(-0.74)	(-0.95)
Industrial complex dummy	-0.006	-0.012	-0.214
	(-0.41)	(-0.71)	(-0.12)
Total assets (Mil KRW)	0.354*	0.007	-0.033
	(1.89)	(0.03)	(-1.60)
Growth in total assets (%)	-0.422	-0.339	-0.021
	(-1.18)	(-0.87)	(-0.51)
Sales growth (%)	-0.455*	-0.969***	-0.058**
	(-1.77)	(-3.45)	(-2.36)
Free cash flow from financial activities/FCFF	0.000	0.000	0.000
	(1.07)	(1.52)	(-0.25)
Free cash flow from investment activities/FCFF	-0.010	-0.008	-0.008
	(-0.82)	(-0.61)	(-0.58)
Foundation year	-0.041	0.064	-7.640
	(-0.19)	(0.27)	(-0.31)
Business group (CEO) fixed effect	Y	Y	Y
Industry fixed effect (five-digit)	Y	Y	Y
R^2	30.0%	31.3%	36.2%
N	535	535	539

while factoring in the CEO and industry-specific fixed effects.

To determine whether the relationship between profitability and the CEO's residential proximity is robust, we employ three different profitability measures while controlling for industry-fixed effects with two separate industry classification codes, one in panel A and the other in panel B. In all of the different classifications, we witness positive correlations between profitability and proximity.

The CEOs of private firms may exert more effort if they see a potential profit in new investment projects. To address this possibility, we control for sales growth and the ages of sample firms. To check whether ongoing capital expenditure projects affect accounting profitability, cash flows from financing and investing activities, scaled by the total free cash flow, are also considered as control variables. Sales growth is found to have a negative impact on accounting profitability. This finding reveals that the firms studied here sacrifice margins to boost their sales turnover.

Next, Table 3 shows the results of firm-level analyses conducted to examine how the selection by a CEO of their residence location is linked to changes in corporate profitability. The regressions in the table use a value in excess of the industry average in the given year, except for changes in the CEO's shareholdings and relocation to an industrial complex. We regress year-over-year changes in the net profit margin on the changes of the distance between the CEO's residence and corporate headquarters along with changes in other control variables. We also use various industry specifications to calculate values in excess of the industry average, but the results are largely unaffected.

TABLE 3—YOY CHANGES IN CEO'S RESIDENTIAL PROXIMITY VS. INNOVATIONS OF EXCESS PROFITABILITY (WITHIN-FIRM ANALYSIS)

This table reports the results of multivariate regressions for which the dependent variable is the year-over-year ("YoY") changes in net profit and explanatory variables include the CEO's residential proximity to the corporate headquarters under the CEOs' control. Other independent variables are changes in the asset growth rate and the YoY evolution of the debt-to-equity ratio. The two independent variables are numbers in excess of the industry average for each year. Fixed effects for the same business group and fiscal year are controlled for in all regression specifications. For each column, the sample period is from 2010 to 2014. For profitability measures, industry averages are calculated based upon four different industry specifications following the Korea Standard Industry Code (KSIC). "KSIC two-digit" is the broadest industry classification, while "KSIC five-digit" is the narrowest. The industrial complex dummy equals one if a firm's headquarters newly moved into one of the industrial complexes specified by the Korea Industrial Complex Corporation. Numbers in parentheses are t-values. ***, **, and * represent the 1%, 5%, and 10% significance levels, respectively.

Industry Classification	Two-digit	Three-digit	Four-digit	Five-digit
YoY changes in distance (100km) (CEO residence vs. HQ)	-0.391***	-0.518*	-0.480***	-0.308***
	(-3.78)	(-1.92)	(-5.51)	(-3.30)
Excess asset growth (%)	-0.366**	-0.720*	-0.443***	-0.345**
	(-2.20)	(-1.65)	(-3.11)	(-2.28)
Changes in excess debt-to-equity ratio	-0.390***	-0.312	-0.298***	-0.250***
	(-4.68)	(-1.42)	(-4.10)	(-3.28)
Changes in CEO's shareholding	-0.990	-0.307	-0.270	0.037
	(-0.49)	(-0.06)	(-0.16)	(0.02)
Industrial complex dummy	-0.048	-0.047	-0.042	-0.049
	(-1.03)	(-0.39)	(-1.06)	(-1.16)
Business group (CEO) fixed effect	Y	Y	Y	Y
Year fixed effect	Y	Y	Y	Y
N	330	330	330	330

The results shown in the table report that as the CEO's residence becomes closer to their corporate headquarters, the net profit margin in excess of the industry average improves. This finding is consistent with the findings in Table 2, showing that there exists a positive relationship between a CEO's residential proximity and their firm's accounting profitability.

Tables 2 and 3 demonstrate the positive relationship between CEO residential proximity and accounting performance. Subsequently, we investigate under what circumstances CEOs relocate closer to their corporate headquarters. In Table 4, we compare the four-year average net profit margin before and after each of the relocations. We then calculate the differences in net profit margin for each relocation instance before and after the relocations and test whether the differences are statistically different from zero. Panel A in Table 4 shows that the net profit margins, on average, are lower before the CEOs relocate to be closer to their corporate headquarters, relative to the margins after this move. The differences in the net margins before and after the relocations are statistically different from zero (*t*-value= 1.84). We interpret this as meaning that the CEOs tend to relocate their residences when they witness the deteriorated level of the net profit margin. Subsequently, the margin improves after the CEOs relocate closer to the head offices, possibly showing greater levels of commitment to their business. In contrast, Panel C in the table shows that the average net margin declines after the

TABLE 4—CHANGES OF NET PROFITABILITY BEFORE/AFTER CEOS MOVE CLOSER (AWAY) TO (FROM) CORPORATE HQS

This table compares the average net profitability of firms before and after the CEOs of private Korean firms relocate their residences closer to the corporate headquarters (panels A and B) or before and after they move further away from the head offices (panels C and D). The average net profitability is the four-year average value of net income/total sales. In panel A, "Before (After) Moving Closer to HQ" indicates the four-year average net profitability before (after) each of the closer relocations occurs. In panels B and D, the difference in the four-year average net profitability between the post-relocation and prior-relocation time points is calculated for each relocation case. The difference is then tested as to whether such a gap is statistically different from zero. "Before (After) Moving Away from HQ" in panel C denotes the four-year average net profitability before (after) each of the CEO relocations resulting in a longer commuting distance for the individuals. Pr > |t| denotes the p-value. ** is the 5% significance level.

Panel A: Four-year Average NP Before/After CEOs Move Closer to HQ					
	N	Mean	SD	Min	Max
After Moving Closer to HQ	46	4.74%	6.48%	-10.06%	24.33%
Before Moving Closer to HQ	46	4.03%	5.70%	-14.30%	19.19%
Panel B: Difference in Average NP (Before vs. After CEOs Move Closer to HQ; Within Firm)					
	N	Mean	SE	*t*-value	Pr > |*t*|
4-yr Post-Relocation minus 4-yr Prior-Relocation	46	0.71%	2.62%	1.84**	7.26%
Panel C: Four-year Average NP Before/After CEOs Move Away From HQ					
	N	Mean	SD	Min	Max
After Moving Away from HQ	83	3.61%	4.02%	-8.76%	16.89%
Before Moving Away from HQ	83	4.29%	3.75%	-3.49%	16.67%
Panel D: Difference in Average NP (Before vs. After CEOs Move Away From HQ; Within Firm)					
	N	Mean	SE	*t*-value	Pr > |*t*|
4-yr Post-Relocation minus 4-yr Prior-Relocation	83	-0.68%	3.49%	-1.78**	7.83%

CEOs move away from the head offices and that the differences in the profitability before and after these types of relocations are statistically significant (*t*-value= -1.78).

Panel A in Table 5 shows the ten-year evolution of the net profit margin before and after CEOs move their residences closer to their head offices. The panel displays a downward trend of the margin before the relocations. The margin marks the lowest level (3.16% with a *t*-value of 2.03) immediately before the CEOs move closer. Profitability shows a slow improvement in the four years after the move. The profit margin eventually revives five years after the CEO relocations.

Panel B in the table displays the evolution of net profitability before and after the CEOs move further away from their corporate headquarters. The evolution of the average profitability in the panel indicates that profitability deteriorates as soon as the CEOs relocate farther from their head offices (t+1). After temporary rebounding (t+2 through t+4), the net margin returns to its lowest level (t+5). The empirical findings from panels A and B in Table V consistently report that private companies regain profitability as the top managers move their residences closer to the firms, while any relocation resulting in the executives having a longer commuting distance coincides with declines in the net profit margin.

The findings in Table 5 suggest a possible scenario about how CEOs react to changing levels of profit margins. It is not until the CEOs witness deteriorated margins for consecutive years that they eventually decide to move their residences

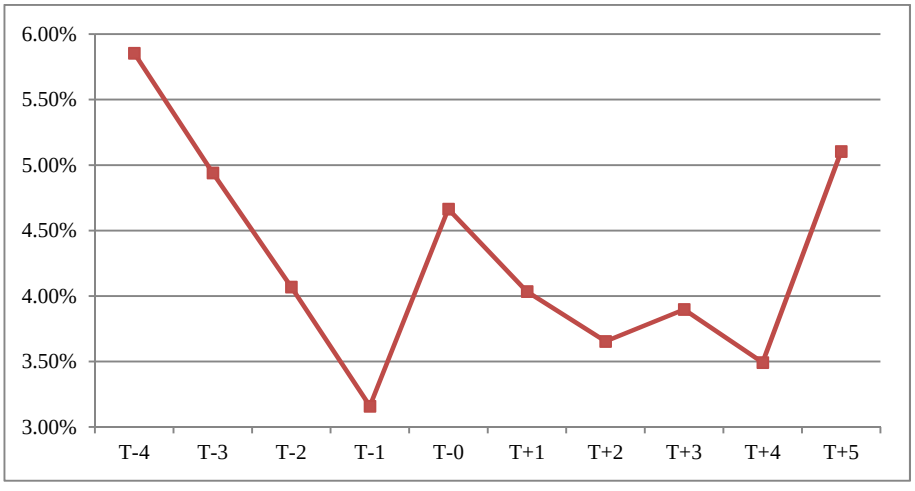
TABLE 5—EVOLUTION OF NET PROFITABILITY AROUND CEOS' RESIDENTIAL RELOCATIONS *TOWARD* CORPORATE HQS

This table shows the changes in the average annual net profitability before and after the CEOs of private Korean companies move their residences closer to the corporate headquarters (panel A) and before and after the top managers move away from the head offices (panel B). The sample period ranges from 2000 to 2014. Average Net Profit means the average net profit of a given year for firms when their CEO moves their residence closer (away) to (from) the headquarters of the company under their control. "Year to CEO's Closer Relocation" presents the year(s) before or after the year of the relocations. Each instance of "Average Net Profit" is tested as to whether net profit is statistically different from zero, and the t-values from such tests are presented along with p-values ("Pr > |t|"). *** and ** stand for the 1% and 5% significance levels, respectively.

Panel A: Evolution of Net Profit Margin When CEOs Move Closer to Corporate HQs							
Year(s) to CEO's Closer Move	N	Average Net Profit	SD	Min	Max	*t*-value	Pr > |*t*|
T-4	39	5.85%	7.16%	-7.47%	34.62%	5.11***	<.0001
T-3	39	4.94%	6.53%	-7.10%	27.01%	4.72***	<.0001
T-2	41	4.07%	6.06%	-13.34%	27.71%	4.3***	0.000
T-1	43	3.16%	10.22%	-44.98%	27.71%	2.03**	0.049
T-0	46	4.66%	8.38%	-25.90%	29.99%	3.78	0.001
T+1	39	4.03%	7.29%	-19.75%	24.33%	3.45***	0.001
T+2	29	3.65%	4.45%	-7.69%	14.83%	4.42***	0.000
T+3	20	3.90%	4.87%	-5.94%	13.83%	3.58***	0.002
T+4	7	3.49%	10.30%	-14.86%	14.88%	0.9	0.404
T+5	7	5.10%	3.84%	0.91%	10.38%	3.51**	0.013
Panel B: Evolution of Net Profit Margin After CEOs Move Away from Corporate HQs							
Year(s) to CEO's Further Move	N	Average Net Profit	SD	Min	Max	*t*-value	Pr > |*t*|
T-2	52	2.99%	6.52%	-16.05%	20.76%	3.31***	0.002
T-1	58	4.50%	5.57%	-6.36%	21.64%	6.15***	<.0001
T-0	83	4.10%	6.06%	-8.76%	41.98%	6.16***	<.0001
T+1	77	2.68%	5.04%	-13.45%	12.42%	4.67***	<.0001
T+2	74	4.52%	5.27%	-5.94%	27.71%	7.38***	<.0001
T+3	64	4.05%	5.55%	-14.86%	15.99%	5.84***	<.0001
T+4	50	3.27%	6.58%	-25.82%	24.33%	3.52**	0.001
T+5	31	2.32%	5.62%	-10.14%	21.25%	2.3**	0.029

closer to their corporate head offices. Considering that CEO residential relocations cannot easily be executed often, the officers decide to move their homes closer to their offices only after finding profit margins have weakened for several years. Once the CEOs decide to commit themselves via their residential relocations, it takes additional years until the businesses that the CEOs manage fully regain healthy profitability. The results in panel A of Table 5 show that it requires five years for such revitalization. After this time, the profit margin rises to 5.10% (*t*-value=3.51), a level similar to where it was four years before the relocations.

Figure 2 provides a visualization of the data in Table 5, showing the evolution of the net profit margins in the ten years before and after the CEOs of Korean private companies moved closer to their corporate headquarters. This figure delivers an easier translation of the results from the table, confirming (1) that the CEOs move their homes closer to the corporate headquarters only after they find weakening profit margins for several years, (2) that they decide to relocate when the margin hits its lowest point, and (3) that it take an additional five years to turn around the sluggish business.



This figure is a visualization of Panel A in Table V, illustrating the time-varying trend of the annual net profit margin around the years when the CEOs of private Korean companies move their primary residences closer to the headquarters of the firms. The sample period is from 2000 to 2014, and the inspection window used to track the trend is ten years across the relocations. T-4 through T+5 denote the years before (after) the CEOs' relocations. Numbers (%) on the vertical axis represent the annual net profit margin.

FIGURE 2. EVOLUTION OF NET PROFITABILITY ACROSS CEOS' CLOSER RELOCATIONS TO CORPORATE HEADQUARTERS

As a final experiment, we study under what circumstances the CEOs of private companies relocate their residences closer to their corporate headquarters. If the motivation behind such relocations is to boost the profitability of the businesses managed by the CEOs, unsound profitability in the past should be linked to the CEOs' decisions. To test this possibility, in panel A of Table VI, we employ logistic regressions, with the dependent variable equal to one if the CEOs move closer to the head office in a given year and equal to zero otherwise. For the regression analyses, we include four-year average changes in the variables. The main component of such explanatory variables is the change of the net profit margin during the four years before the CEOs moved closer to the corporate head offices. Alternative possibilities are that (1) only certain types of CEOs or firms undertook residential relocations, and/or (2) only CEOs managing firms belonging to specific industries show such behavior. To control for these possibilities, we run the logistic regressions while taking fixed effects into account. In two of three regression specifications in panel A, poor performance in past influences CEOs to relocate closer to their corporate headquarters at 10% significance level.

Panel B in the table also shows how past performance is related to CEO relocation decisions, but based on a different specification. The dependent variable is a continuous variable, reflecting the changes in distance from previous years while explanatory variables include changes in the net profit margin at *t*-1. For this analysis, we only consider cases where the CEOs move closer to the headquarters by more than 10 kilometers. We find that the past year's decline of net profitability

is significantly related to the decision by the CEO to move closer. In detail, every decline by one basis point in net profitability results in the CEOs relocating their homes approximately two kilometers closer to the corporate headquarters. We do not find any significant relationship between minor distance changes (less than 10 kilometers) and previous net profitability. This type of reduction in the sample may hamper the reliability of our empirical tests, but apparently a more substantial relocation (a reduction of more than 10 kilometers in terms of the commuting distance) better captures the possibility that top executives move their homes closer to their corporate headquarters with serious resolutions. If a CEO decides to relocate closer to the headquarters to supervise her business more intensively, it makes more sense to move much closer to it rather than merely to move within same local community. We acknowledge that the small sample size in panel B may affect the reliability of the tests.

The results in Table 6 confirm that CEOs tend to relocate their residences closer to their headquarters when a negative trend in net profitability arises in the previous four years. Additionally, we find that the CEOs of such businesses are more likely to move closer to larger businesses (see the results from models 1 and 2 in the table). The positive relationship between CEO relocations and the size of the business implies that CEOs move closer to their head offices when their businesses are large, thus requiring of the CEOs more attention to their enterprises.

IV. Conclusion

Existing literature suitably documents what drives corporate CEOs to exert themselves to see their businesses thrive, mostly examining their motivation to maximize their expected monetary compensation. However, the literature rarely finds any specific channel through which CEOs commit to improve the management or performance of their companies. In this paper, using a unique dataset containing CEO residential information, we present a detailed examination of one channel by which CEOs dedicate themselves to better manage their companies.

For econometric concerns, residential relocation is not an event that occurs often and, therefore, year-over-year changes in residential proximity are seldom pronounced. This non-volatile nature of the variables (e.g., year-over-year changes in residential proximity) inflates the clustered standard errors for most of our analyses, weakening the power of this analysis. This caveat is inevitable considering the invariant nature of residential relocations. We explicitly acknowledge this concern and admit that the distinction can potentially exaggerate the power of such empirical tests.

The changes in residential addresses in this study are only detectable when the CEOs report such changes whenever they occur. When individuals fail to report to the public corporate registration system (www.iros.go.kr), the changes in their physical addresses become undetectable. In this sense, our analyses possibly omit cases in which CEOs actually move their residences but such relocations are not captured in our sample due to their failure to report the changes to the public registration system.

Studying a group of private companies managed by the same CEO while considering various fixed effects during the different analyses partially diminishes the risk of concluding false causation but admittedly is far from being complete. This paper nonetheless contributes to the current literature by presenting a new way to measure the level of CEO commitment.

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Household Debt and Consumer Spending in Korea: Evidence from Household Data†

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Household debt in Korea raises concerns about the resilience of the economy due to its size and quality. Against this backdrop, we investigate if household leverage matters for private consumption in adverse economic environments even without severe financial disruptions. We find that the balance sheet positions in terms of the leverage ratio may weaken consumption growth. We also find that the depressive effect of debt on consumption may differ across types of consumer spending and household characteristics. In particular, the effects of indebtedness have been much stronger in relation to durable goods expenditures than in other areas. In addition, debtors in high-income (wealth) groups have also shown downward adjustments in consumption even more so than low-income (wealth) groups. These findings imply that debtors' precautionary behavior may serve as an important channel from leverage to consumer spending.

Key Word: Household debt, Consumption, Leverage
JEL Code: D12, E21, E30

I. Introduction

Household debt in Korea has raised concerns about economic resilience as the accumulated debt has been large relative to income (or GDP) when compared to many other countries. The Korean economy entered a deep recession at the onset of the global financial crisis of 2007-09 and then slowed down again in 2011-13 after a very short-lived recovery in 2010. Consumption growth was also very weak during the two periods of adverse macroeconomic conditions. It is often claimed that the high leverage of the household sector may drag down domestic demand, but without much empirical evidence. Against this backdrop, we investigate if

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household balance sheet positons have aggravated private consumption in the face of contractionary developments in the economy.

Consumer spending may differ between households with high and low leverage, as high leverage may hinder households from increasing consumption expenditures, especially in times of adverse economic conditions. Highly leveraged households may show weaker consumption growth compared with other households because they may behave in a more precautionary manner out of fear of financial distress in the future or worry over limited access to credit. We ask in the current study how heterogeneity in household balance sheet positions in terms of leverage may explain the difference in the strength of consumer spending, especially under adverse macroeconomic conditions even with appropriately controlling for the common determinants of consumption, such as income, wealth and other relevant factors. In addition, we analyze various aspects of the debt-consumption relationship across different types of consumption and household characteristics for the two adverse economic environments in 2007-09 and 2011-13.

We find arguments in previous studies holding that household indebtedness matters with regard to consumer spending. Mishkin (1976, 1977, 1978) argues that the composition of household balance sheets influences the spending decisions of the household, especially on illiquid assets such as durable goods and house purchases. For example, household obligations such as a high debt burden would depress the demand for consumer durables even if the net worth remains constant. King (1994) argues that household indebtedness can destabilize the real economy by depressing aggregate consumption. Eggertsson and Krugman (2012) also show that a large deleveraging shock may induce debtors to reduce consumption by a large amount while savers (or creditors) may not increase their consumption enough to compensate for the consumption decline by debtors under some circumstances. Betti *et al.* (2007) argue that too much debt accumulation based on erroneous beliefs about the future would result in adjustments in consumption expenditures if the beliefs or expectations about future incomes were shown to be false by actual outcomes.

Based on the above theoretical arguments, we analyze at the household level how heterogeneity in the leverage of households or in their balance sheet compositions affects the consumption behavior, ceteris paribus, i.e., conditional on other common determinants of consumption. Consumption may be determined by income (Y), wealth (NW), and household characteristics according to previous studies. In addition to the common determinants, the analysis conducted here examines if household leverage can exert downward pressure on consumption expenditures in the event of adverse macroeconomic developments.

We find that highly leveraged households tended to show weaker consumption growth compared with other households in the recession driven by the global financial crisis as well as in the recent economic slow-downs without much financial disruptions. In other words, weakness in the balance sheet position may exert downward pressure on household consumption in times of adverse macroeconomic conditions with high uncertainty about the future. In addition, we find that household leverage had much stronger effects on durable goods purchases than nondurable consumption, confirming based on a household-level analysis Mishkin's (1976)

argument about the depressive effects of debt on consumer durables. We also find depressive effects of leverage on consumption in both low-income (wealth) and high-income (wealth) households, with the effects even stronger in the latter group. This result suggests that debtors' precautionary responses may have played an important role in their weak consumption growth amid the worsening economic conditions with uncertainty and looming associated economic prospects.[1] In addition, we find that the effects of household leverage on consumption were greater in 2011-13 than in 2007-09. The weakness in consumption growth shown by leveraged households even in the less disruptive macroeconomic environment in more recent years (2011-13) suggests that households' balance sheet positions during these recent events may be more depressing with respect to private consumption. It is important to note that the rising share of highly leveraged households in combination with the depressive effect of leverage may exert greater downward pressure on private consumption if the economy is hit by severe shocks. From a policy perspective, the current study suggests that attention may be warranted with regard to the soundness of household balance sheets for the real economy, especially in times of worsening economic conditions.

The current study is closely related to those by Dynan (2012), Andersen *et al.* (2014), and Son and Choi (2015) in that it undertakes an investigation of the debt-consumption relationship based on household data with similar empirical methods. These earlier works all focus on the recessionary environment due to the global financial crisis (2007-09). In contrast, we show that leveraged households adjusted their spending not only during the deep recession driven by the global financial crisis (2007-09) but also during the decelerating economic environment in its aftermath (2011-13). In other words, the weak balance sheet positions of households may matter for the real economy during worsening economic environments even without severe disruptions in financial markets or intermediaries. We find that the effect of leverage on consumption growth was even stronger during the decelerating economic environment of 2011-13 than it was during the recession of 2007-09. In addition, we show how the depressive effect of household debt on consumption may differ across different types of consumer spending and household characteristics, as mentioned above. In particular, we find that household indebtedness has a stronger effect on consumer durables than on non-durables. In addition, the downward adjustment in consumption expenditures is strong even for high-income (wealth) households, suggesting that debtors' precautionary behavior may serve as an important channel from leverage to consumer spending.

The remaining of this paper is organized as follows. Section II discusses related studies, while section III describes the macroeconomic environment behind the current study as its motivational economic background. Section IV describes the data with relevant descriptive features used in the current empirical study, while section V discusses the empirical specifications. Section VI estimates the empirical specifications in the two periods (2007-09 and 2011-13) and discusses the results. Section VII ends with a summary and a discussion of related policy issues.

[1]See Romer (1990), who argues that high uncertainty depressed private consumption during the Great Depression in the US.

II. Relationship with Previous Studies

We can find theoretical arguments in literature that household indebtedness affects consumer spending. Mishkin (1976, 1977, 1978) suggested the illiquidity hypothesis, which holds that certain aspects of household balance sheets, such as liabilities, may influence households' levels of demand for illiquid assets such as durable goods and houses. For example, changes in the composition of household balance sheets in terms of liabilities (or financial asset holdings) would affect the demand for consumer durables even if net worth remains constant. If households' balance sheets deteriorate due to large household debt accumulation, consumer spending on illiquid items in particular would be severely depressed because more indebted households may fear financial distress in the future. King (1994) extends Fisher's (1933) original debt deflation theory and shows based on a theoretical model that household indebtedness can destabilize the real economy. According to King (1994), debtors' consumption functions may differ from those of creditors' such that their aggregation may result in a state of unstable macroeconomic equilibrium, in which aggregate consumption can be somewhat depressed. He argues that debt deflation theory may help us to understand the economic declines experienced by northern European countries in the 1990s. Eggertsson and Krugman (2012) also use debt-deflation theory to show based on a macroeconomic model with heterogeneity in household indebtedness taken into account that large deleveraging shocks can push the economy into much deeper recessions. Deleveraging shocks or a large decline in the desired level of leverage, due to uncertain income prospects for example, may induce debtors to reduce their consumption by a large amount, while savers (or creditors) may not increase their consumption enough to compensate for the consumption decline by debtors. Olney (1999) argues that the costs associated with defaults may result in large household spending cuts. Based on an empirical analysis of the relationship between defaults and consumer spending during the Great Depression, he concludes that the high costs of defaults forced households to make large spending cuts, especially in the face of uncertain income prospects. Hence, the difference in costs associated with consumer defaults may play an important role in consumer choice, especially in times of uncertain income prospects. Betti *et al.* (2007) link household over-indebtedness to too much consumption spending that is not sustainable in the long run. For example, over-indebted households will adjust their consumption expenditures when their expectation of future income is adjusted or shown to be false by actual outcomes. In this sense, too much debt accumulation based on incorrect beliefs about the future may result in adjustments in future consumption expenditures.

We may find empirical studies broadly related to the current study, which analyzes the relationship between household debt and the real economy in general. These previous studies conduct their analyses at various levels, from cross-country to household-level studies. Cross-country analyses of household debt and subsequent economic outcomes can be found in Bouis (2014), Jorda, Schularick, and Taylor (2013), Cecchetti *et al.* (2011), and Glick and Lansing (2010), among others. In addition to cross-country studies, there are cross-sectional analyses at the

state level or county level, as conducted by Mian, Rao, and Sufi (2013), Mian and Sufi (2010), and Gartner (2013), among others. We can also find Glick and Lansing (2009) and Olney (1999), who base their analyses on macro-level data in the US. These empirical studies indicate that the rapid accumulation of too much debt tends to be followed by an economic downturn of various depths and protracted recoveries; hence, household debt likely influences economic activity.

Close to the current study based on a household-level analysis but in a different empirical framework are Ogawa and Wan (2007) and Kim and Kim (2012). Ogawa and Wan (2007) study the debt-consumption relationship based on Japanese household data and argue that debt-asset ratios had negative effects on household consumption mainly through borrowing constraints when the bubble burst in the 1990s. Kim and Kim (2012) analyze the time frame of 2000-07 from the Korea Labor and Income Panel Study (KLIPS) and argue that household debt accumulation increased consumption by relaxing credit constraints during the sample period.

Studies fairly closely related to the present study with similar empirical frameworks were conducted by Dynan (2012), Andersen *et al.* (2014), and Son and Choi (2015). Dynan (2012) argues that the high leverage of households prior to the financial crisis may have weakened the recovery of consumption growth in the U.S. in the post-crisis years. Andersen *et al.* (2014) also study how the ex-ante level of household leverage may have affected the dramatic downturns in the Danish household sector in terms of the change in consumption expenditures in the post-crisis era. In line with these previous studies, Son and Choi (2015) analyze KLIPS data and argue that household leverage prior to the global financial crisis may be related to the downturns in consumption growth during the post-crisis years. In short, all of these studies analyze how the ex-ante leverage of households may be related to the ex-post recovery of consumption growth in the face of the deep recession during the global financial crisis of 2007-09. The current study complements earlier work by analyzing the impact of ex-ante household leverage on subsequent consumption behavior during the dramatic recession linked to the global financial crisis (2007-09) as well as the decelerating macroeconomic environment in recent years (2011-13). In addition, we shed light on other aspects of the debt-consumption relationship by analyzing different types of consumer spending and household characteristics. In terms of empirical specifications, we account for differences between debtors and non-debtors in terms of consumption behavior as well.

III. Background Economic Conditions

Household debt in Korea has increased relative to household income (or GDP) with only slight adjustments in 2007-08 and 2011-13 but without significant deleveraging processes, as shown in Figure 1, in contrast to countries that went through dramatic deleveraging phases amid the global financial crisis. The amount of household debt relative to income is high even compared to many other countries. The large accumulation of household debt relative to income suggests

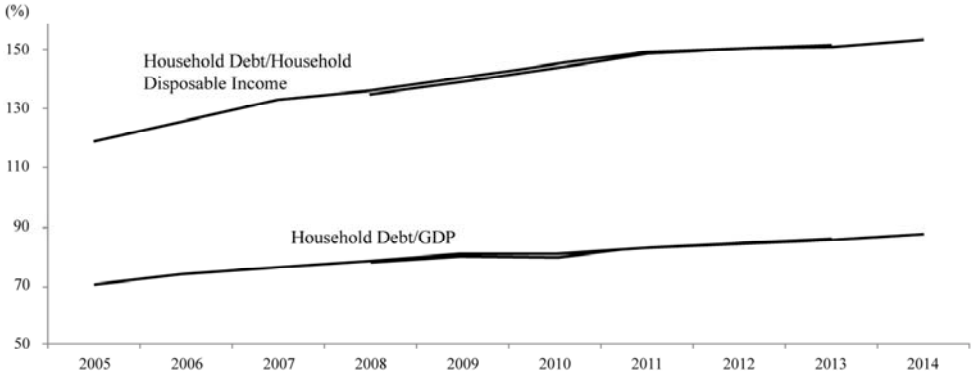

FIGURE 1. AGGREGATE HOUSEHOLD DEBT RELATIVE TO HOUSEHOLD INCOME AND GDP

Source: Flow of Funds (1993 SNA, 2008 SNA) and National Accounts from the Bank of Korea.

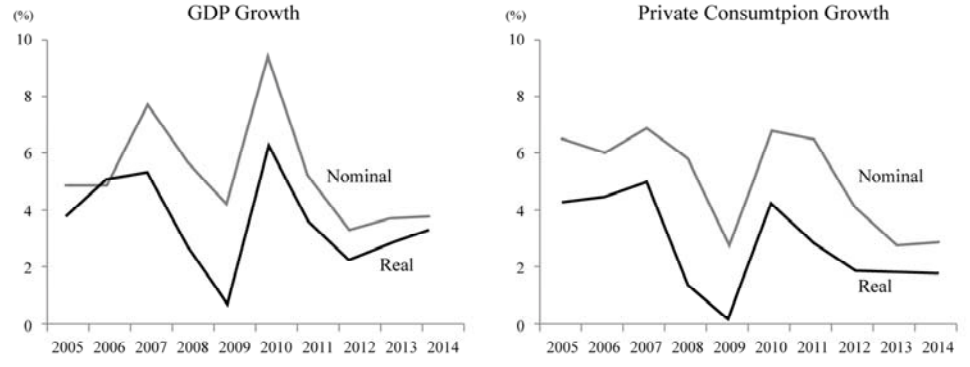

FIGURE 2. GDP AND PRIVATE CONSUMPTION GROWTH RATES

Source: National Accounts from the Bank of Korea.

that the balance sheet positions of the household sector have weakened.[2] Against this backdrop, household debt has often been cited as a contributing factor to the weak domestic demand after the global financial crisis, but without much evidence.

During the global financial crisis, the Korean economy experienced a deep recession. Figure 2 shows that the real GDP growth rate dropped from 5.3% in 2007 to 0.7% in 2009. Although the economy recorded a temporarily high GDP growth rate of 6.3% in 2010 immediately after the crisis, the real GDP growth rate dropped again to 2.3% in 2012, much lower than the average growth rate during the pre-crisis era. The weakening economic activity since 2010 as shown in Figure 2 may be partly due to the weak recovery of the global economy given the European fiscal and financial turmoil with the high levels of uncertainty.

We observe patterns in private consumption similar to that of GDP growth, as shown in Figure 2. Private consumption recorded a historically low real growth

[2]See Kim, Lee, Son, and Son (2014), Kim and Yoo (2013), and Kim and Byun (2012) among others for detailed descriptions and assessments of household debt in Korea.

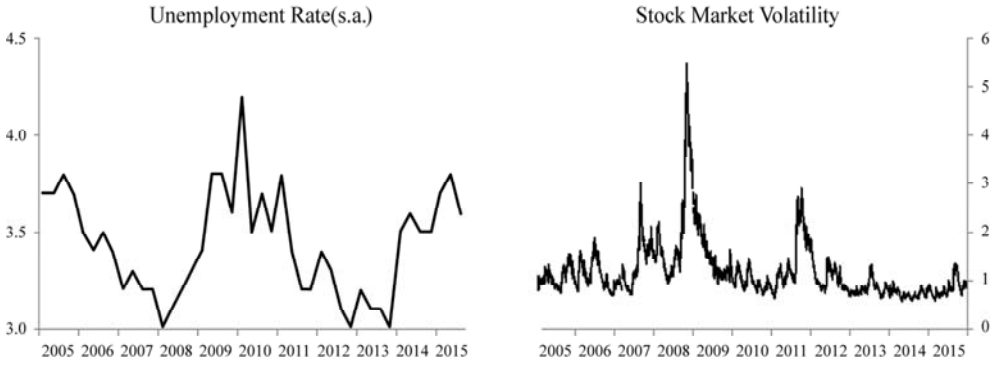

FIGURE 3. UNEMPLOYMENT (SEASONALLY ADJUSTED) AND STOCK MARKET VOLATILITY

Note: The stock market volatility is the GARCH (1,1) standard deviation of the daily returns from the KOSPI index.

Source: Statistics Korea, Korea Exchange.

rate of 0.2% in 2009, a large drop from the rate of 5% in 2007. After a temporary sharp rise up to 4.3% in 2010, the real consumption growth rate declined again to 1.9% in 2013 and has remained low in the subsequent years in comparison with the pre-crisis era. The weak consumption growth experienced by the household sector may also have put downward pressure on the overall economic activity. These macroeconomic conditions are the motivational background against which we attempt to analyze how the weak private consumption shown in Figure 2 may be related to the unprecedentedly high leverage of households.

Turning to the economic recession in 2008-09, the unemployment rate increased and remained relatively high for a while even after the financial crisis, as shown in Figure 3.[3] As the economy came out of the recession, the unemployment rate gradually declined in 2011-13 to pre-crisis levels. As a measure of uncertainty, we can also observe stock market volatility.[4] Stock market volatility jumped to very high levels at the onset of the financial crisis and then declined moving out of the recession. In the face of the European fiscal crisis (2011-12), stock volatility jumped again but to a lesser extent than that during the global financial crisis (2008-09). It is important to note the greater magnitude of the degree of uncertainty and the sizes of shocks, which were greater during the global financial crisis than during the subsequent period of European turmoil. High uncertainty and pessimistic views about the future amid the worsening macroeconomic development may have affected the perceptions of indebted householders of their desired debt levels; hence, some of them may have adjusted their spending downward in a precautionary manner, contributing to the weakness of private consumption growth, as shown in Figure 2. We expect that high uncertainty and more pessimistic views of the economy likely exerted more downward pressure on

[3]Hall (2012) pays particular attention to the level of unemployment as a major indicator of 'the slump.'

[4]Romer (1990) uses stock market variability as a measure of uncertainty to analyze its impact on the consumption contraction during the Great Depression in the US. We can also refer to Engle, Ghysels, and Sohn (2013); Hamilton and Lin (1996); and Schwert (1989), among others, who link stock market volatility to real economic activity.

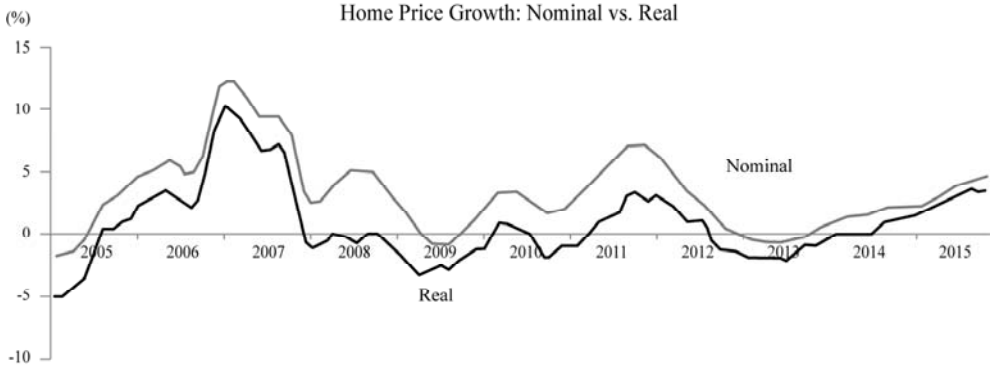

FIGURE 4. HOME PRICE GROWTH: NOMINAL VS. REAL RATES

Note: The grey line is the nominal annual% change and the black line is the real annual% change.

Source: Housing Purchase Price Index from KB Kookmin Bank.

consumer spending.

Amid the recession during the global financial crisis of 2007-09, the housing market also experienced depressive pressure, as shown in Figure 4. As macroeconomic conditions worsened again in 2011-13, though not as dramatically as in the financial crisis period, the housing market also faced downward pressure, as shown in Figure 4. The depressive developments in the housing market likely eroded the net worth of homeowners while damaging the balance sheet positions of highly leveraged homeowners in particular. We expect that those indebted and with weak balance sheet positions adjusted their spending behavior in the face of the downward pressure in the housing market, as they were likely to face difficulties in accessing credit or may have found that their current debt levels were not desirable. It should also be noted that there have been depressive developments in the housing market both in 2007-09 and 2011-13, through the downward pressure was greater and lasted longer during the global financial crisis era of 2007-09.

Along with the downward pressure in the housing market during the two periods (2007-09 and 2011-13), credit market conditions also turned unfavorable. A survey on lending practices suggested that households' accessibility to credit worsened during the crisis period and during 2011-13, as shown in Figure 5. The tightened credit standards may have influenced the consumption smoothing behavior of households during this time, especially for highly leveraged households or those in the low-income brackets with liquidity constraints. We may note that the regulatory LTV (loan to value) ceiling of bank loans had been set at 60%, until it was raised to 70% in August of 2014; hence, those high LTV borrowers may have had difficulty in accessing credit for additional loans. We expect that households' spending behavior may have been affected by credit standards but at different degrees depending on their leverage ratios.

We consider adverse macroeconomic conditions during the two periods of 2007-09 and 2011-13 in the analysis of the relationship between ex-ante household leverage and subsequent consumption growth. As discussed above, the former period is a recession characterized by high uncertainty and bleak future prospects with the housing market under downward pressure and credit market conditions

FIGURE 5. SURVEY ON LENDING PRACTICES: LENDING ATTITUDE AND CREDIT RISKS

Note: The grey lines are the four-quarter moving averages of each survey (in black lines).

Source: Survey on Lending Practices from the Bank of Korea.

tightened. The latter period also shows deceleration in economic activity overall but at less severe levels than in the former period. In short, the two periods (2007-09 and 2011-13) are characterized by worsening economic conditions while the former period involved a more adverse shock. We expect that household indebtedness likely influenced consumer spending in these times of adverse macroeconomic conditions. Against this background, we investigate how ex-ante household leverage may be related to subsequent consumer spending.

IV. Data and Descriptive Statistics

The current study uses the National Survey of Tax and Benefit (NaSTaB) as the household-level panel data set for the empirical analysis. The NaSTaB data set has been compiled and released annually since the first interview in 2008. This nationwide survey asks individuals and households about their economic activities and well-being mostly during the previous year in broad categories such as income, consumption, wealth, liabilities, taxes and benefits every year in an effort to understand the household sector. The data set involves 5,634 households which are surveyed yearly.[5] The NaSTaB data used in the current empirical study contain rich information about consumption while covering the two periods of the recession of 2007-09 and the recent (2011-13) economic slow-down.

In order to analyze how households' financial positions are related to their consumption behaviors, we extract household-level information about their balance sheets and income-expenditure flows from the NaSTaB data set. Among the variables of interest, disposable income is calculated as the total sum of household income excluding non-consumption expenditures such as taxes and social security

[5]As an alternative data set with detailed information about the financial conditions of households, we may consider the Survey of Household Finances (SHF). However, the SHF does not contain much information about the consumption side of households, while it started in 2010, a few years after the global financial crisis.

TABLE 1—SUMMARY STATISTICS

(UNIT: 1,000KRW)

Year	2007	2009	2011	2013
Current Income	32,398	34,220	37,405	39,278
Non-current Income	2,223	2,824	2,128	1,190
Consumption expenditures	18,616	24,207	24,449	25,560
Non-consumption expenditures	5,652	6,149	6,811	7,997
Financial Asset	23,193	25,725	29,285	32,803
Real Estate Asset	184,816	183,740	202,201	217,022
Debt	34,198	34,649	39,382	40,396
Net Worth	176,291	176,575	193,483	209,909

Note: The numbers are average values in 1,000 KRW currency units. Among the variables, current income denotes regular sources of income covering labor income, asset income, net business income, social security income, transfer income, and other regular income. Non-current income is irregular or temporary sources of income such as inheritances and gifts. Adding all of the subcategories of current and non-current income gives the total household income. Non-consumption expenditures consist of income tax, property tax, pension payments, social security payments, transfer payments, and other similar payments.

Source: National Survey of Tax and Benefit, Korea Institute of Public Finance.

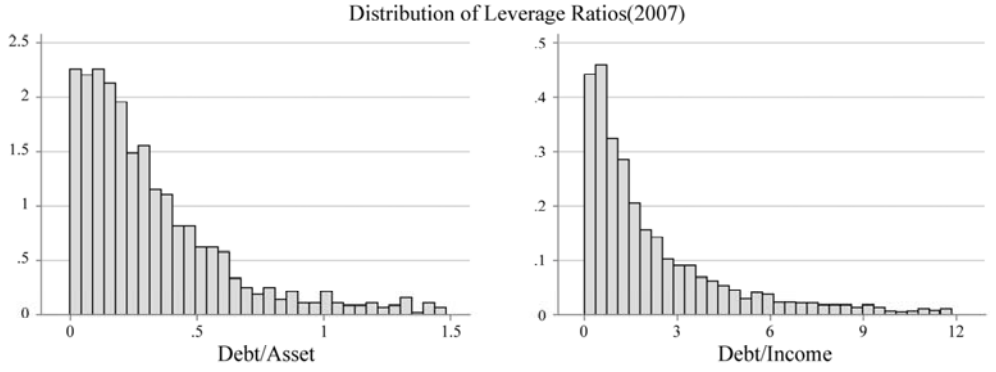

FIGURE 6. DISTRIBUTION OF DEBT-TO-ASSET AND DEBT-TO-INCOME RATIOS IN 2007

Note: The left and right panels show the distribution of the total debt to total asset ratios and the distribution of the total debt to disposable income ratios, respectively, for indebted households in 2007.

payments.[6] Consumption expenditures, total assets, and the total debt of each household are calculated as the total sums of all of their respective sub-categories. Net worth is the difference between total assets and total debts. Table 1 shows the summary statistics of several major variables of interest. As a measure of the leverage ratio for each household, we consider total debt (D)/total assets (A), net worth (NW)/total assets (A), and the total debt/disposable income ratio. We may note that the D/A and NW/A ratios contain essentially the same information as a measure of the balance sheet composition because $\mathrm{NW/A}=\left(\mathrm{A-D}\right)/\mathrm{A}=1-\mathrm{D/A}$.

The current study investigates how households' balance sheet positions affect the behaviors of the households as consumers. In particular, we pay attention to the heterogeneity of household leverage as a possible determinant that affects consumption decisions. Below we show how households differ in terms of their

[6]See the notes below Table 1 for detailed information about the income categories of the NaSTaB data set.

leverage ratios. We consider the total debt/total assets and total debt/disposable income ratios as measures of household leverage. Figure 6 shows the distribution of the debt-to-asset and debt-to-disposable income ratios for indebted households in 2007. In the figure, we find much heterogeneity in leverage ratios across indebted households. We also note that households are heterogeneous in terms of their net asset ratios because the net asset ratios contain essentially the same information about the balance sheet composition as the debt-to-asset ratios. In other words, the net worth buffers, working as cushions against potential financial distress, are different across households. Thus, the heterogeneity in leverage ratios may indicate different degrees of resilience across households against an adverse economic environment. We examine how the ex-ante heterogeneity in households' leverage ratios is related to the subsequent consumption behavior of the household in the face of adverse economic conditions.

V. Empirical Specifications

In this section, we establish empirical specifications to analyze how household leverage may affect consumption behavior in the face of adverse economic environments. We are interested in the two periods of 2007-09 and 2011-13, during which macroeconomic conditions worsened but in different degrees, as discussed above. In the current study, we ask if households' indebtedness contributed to the weakness in their consumption expenditures during the deep recession of the global financial crisis of 2007-09 and during the decelerating macroeconomic conditions of 2011-13. From the perspective of business cycle research, this question asks whether households' indebtedness or balance sheet positons can amplify the depth and/or duration of the downward pressure on aggregate economic activity. We often encounter such claims from news media and from policy circles, who state that unprecedentedly large amounts of debt can be blamed for the continuing weakness in private consumption since the global financial crisis, but without much empirical evidence. The current study aims to address this issue by providing evidence based on household data analysis.

In order to address this issue, we set out a baseline regression specification which may explain how consumption growth is determined with household debt taken into account. Reflecting on previous arguments pertaining to wealth as a determinant of consumption, we take net worth as a major determinant of consumption in addition to income.[7] In addition to the net worth component of the balance sheet, we ask how a balance sheet composition in terms of the leverage ratio can affect consumer spending. It is important to note that the net worth component itself does not tell us much about the composition or vulnerability of the balance sheet. In contrast, such leverage ratios as the debt-to-asset ratio (=D/A) or the net-worth-to-asset ratio (=NW/A) may measure the composition of the

[7]As possible channels from wealth to consumption, such arguments as wealth effects, collateral constraints, common factors, and financial liberalization are discussed in the literature, although some of these arguments remain under debate (Browning, Gørtz, and Leth-Petersen 2013). See also Disney, Gathergood, and Henley (2010); Campbell and Coco (2007); and Iacoviello (2004), among others, for more discussions on the effects of wealth on consumption.

household balance sheet because the size of the balance sheet (asset; A) equals debt (D) plus the net worth (NW). To explain how vulnerability in the balance sheet composition may affect consumer spending, we incorporate the heterogeneity in household leverage ratios into the empirical specification as a potential factor that affects consumption behavior. In addition, we consider that debtors (borrowers) may show different consumption behaviors from non-debtors (savers) mainly due to their different preferences, as discussed by Eggertsson and Krugman (2012) and by King (1994), among others.

Reflecting on the above discussions, we examine the following empirical specification as a baseline regression model in order to answer the questions at hand.

The baseline regression specification is as follows:

$$\Delta C_{i,t_0-t_1} = \beta_0 + (\beta_1 + \beta_2 * Lev_{i,t_0}) * D\_dum_{i,t_0} + \beta_3 \Delta Y_{i,t_0-t_1} + \beta_4 \Delta NW_{i,t_0-t_1} + \beta_5 \Delta HHsize_{i,t_0-t_1} + \beta_6 X_{i,t_0} + \varepsilon_i \quad (1)$$

Here, $\Delta C_{i,t_0-t_1}$ is the change in the consumption expenditures of household i in the period from t_0 to t_1. Lev_{i,t_0} is the leverage ratio of household i at t_0, the beginning of the period in which macroeconomic conditions worsened. D_dum_{i,t_0} is a dummy variable that represents the indebtedness of household i at t_0; hence, $\left(\beta_1 + \beta_2 * Lev_{i,t_0}\right)$ can be interpreted as the difference in consumption growth rates between debtors and non-debtors while $\beta_2 * Lev_{i,t_0}$ can explain the difference between debtors with different leverage ratios. As a measure of Lev_{i,t_0}, we consider the debt/asset (D/A) or debt/income (D/Y) ratios. Note that the debt/asset ratio contains information identical to that associated with the net worth buffer (=net worth/asset), as discussed earlier. In the specification, $\Delta Y_{i,t_0-t_1}$, $\Delta NW_{i,t_0-t_1}$, and $\Delta HHsize_{i,t_0-t_1}$ denote the change in disposable income, the net worth, and the family size of household i in the period from t_0 to t_1, respectively. $\Delta Y_{i,t_0-t_1}$ may be relevant to liquidity-constrained or myopic households whose consumption levels may be affected by their income changes. The household size $\left(\Delta HHsize_{i,t_0-t_1}\right)$ can explain the hump-shaped pattern of the lifetime consumption profile.[8] X_{i,t_0} is a vector of other variables at t_0 that may influence subsequent consumption changes, such as household characteristics that may reflect consumer preferences - e.g. X_{i,t_0} may include educational attainment levels and demographic structures. For example, older householders in retirement may be more sensitive regarding their consumption in response to poor economic

[8]See Attanasio *et al.* (1999) and Attanasio and Weber (1995), among others, about the relationships between changes in family compositions and consumption growth.

conditions with uncertainty and tight credit standards. $(t_0 \text{ and } t_1)$ represent (2007, 2009) for the recession of the global financial crisis and (2011, 2013) for the recent economic slow-down, respectively. We also examine alternative specifications as variants of the baseline model (1) to address the relevant issues at hand.

Note that C, Y, and NW in the above specification are 'inverse hyperbolic sine' transformed,[9] respectively, as suggested by Dynan (2012). This type of transformation can incorporate such cases with zero or negative (-) variables while dealing with extreme values in micro-data sets. For example, there may be many households with a negative (-) 'net worth'; hence, taking the logs of such variables may reduce the sample size while excluding the relevant households from the regression analysis. As noted by Dynan (2012), the interpretation of this type of transformation may be similar to that of a logarithmic transformation except for the very small values. For the use of and discussion about this transformation, see Carroll, Dynan, and Krane (2003); Dynan (2012); Browning *et al.* (2013); and Burbidge *et al.* (1988), among others.

We consider differences in consumption types, income and net worth levels in the following analyses of consumer behavior in relation to leverage. Taking the differences in those categories into account may shed some light on the possible channels from household leverage to consumption behaviors while providing useful guidance for policy directions. For example, household expenditures can be divided into those for durable goods and non-durables because the demand for durables may be more sensitive to uncertainty and credit standards than that for non-durables. Hence, the responses pertaining to durables may be more dramatic in times of more adverse economic downturns. In addition, we divide households into low- and high-income (wealth) groups because low-income (wealth) families are likely to be liquidity-constrained, whereas high-income (wealth) families tend to be less liquidity-constrained with high saving rates. We compare low-income (wealth) households with high-income (wealth) groups to shed light on the role of uncertainty in comparison with credit standards.

VI. Estimation Results and Discussions

We examine below how households may have responded in terms of their consumption expenditure in relation to their leverage ratios during the global financial crisis (2007-09) as well as in the recent years of the decelerating macroeconomic conditions (2011-13). As measures of the leverage ratio, we consider the ratio of total debt to total assets (D/A) and total debt to disposable income (D/Y). The baseline specification (1) and its variant forms are estimated for each period as discussed above and the main results are reported in Table 2 ~ Table 4. For the estimations, outliers in the leverage ratios are excluded from the sample.

Table 2 shows the baseline regression results for each respective period: 2007-09 vs. 2011-13. We find that indebtedness shows significant and negative effects on consumption expenditure growth, suggesting that the liability side of balance sheet

[9] 'Inverse hyperbolic sign' transformation of $x = \log(x+(x^2+1)^{1/2})$

TABLE 2—BASELINE REGRESSIONS EXPLAINING CONSUMPTION GROWTH

	ΔConsumption in 2007-09					ΔConsumption in 2011-13				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
D_dum[a]	-0.100**			-0.073**	-0.072**	-0.138**			-0.098**	-0.080**
	(0.025)			(-0.029)	(-0.028)	(-0.024)			-0.028	-0.027
D/A[a]		-0.114**					-0.180**			
		(0.032)					(-0.034)			
D/Y[a]			-0.016**					-0.029**		
			(0.004)					(0.004)		
(D/A)*D_dum[a]				-0.070**					-0.116**	
				(0.036)					(0.038)	
(D/Y)*D_dum[a]					-0.011**					-0.022**
					(0.005)					(0.005)
ΔIncome	0.136**	0.135**	0.141**	0.135**	0.139**	0.207**	0.206**	0.223**	0.206**	0.219**
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
ΔNet Worth	0.007**	0.011**	0.007**	0.010**	0.007**	0.008**	0.014**	0.008**	0.012**	0.008**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
ΔFamily Size	0.161**	0.161**	0.162**	0.160**	0.161**	0.175**	0.176**	0.177**	0.174**	0.175**
	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
(40s_50s)_dum[a]	0.01	0.001	0.012	0.007	0.014	-0.003	-0.019	-0.001	-0.009	0.003
	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
(After_60)_dum[a]	-0.103**	-0.108**	-0.085**	-0.109**	-0.095**	-0.021	-0.034	0.007	-0.032	-0.003
	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)
Education[a]	-0.011	-0.015*	-0.011	-0.012	-0.01	-0.015*	-0.021**	-0.016*	-0.017*	-0.014
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Const.	0.272**	0.271**	0.240**	0.283**	0.264**	0.127**	0.128**	0.088	0.140**	0.109*
	(0.054)	(0.054)	(0.053)	(0.054)	(0.054)	(0.056)	(0.056)	(0.055)	(0.056)	(0.056)
Adj. R^2	0.044	0.043	0.043	0.044	0.045	0.077	0.076	0.079	0.079	0.081
# Obs.	3,791	3,791	3,791	3,791	3,791	4,236	4,236	4,236	4,236	4,236

Note: * p<0.1, ** p<0.05. [a] indicates the beginning of each period: 2007 for the sample period of 2007-09 and 2011 for the sample period of 2011-13. ΔIncome, ΔNet Worth, ΔFamily and Size are changes in income, net worth, and family size, respectively. D_dum is a dummy variable for debt holdings. D/A and D/Y are the debt-to-asset and debt-to-income ratios, respectively. (40s_50s)_dum and (After_60)_dum are dummy variables denoting a householder aged 40-60 and after 60, respectively.

vulnerability affects their consumption behavior. It should be noted that the impact of household indebtedness on consumption growth is stronger in 2011-13 ((1)~(5)) than in 2007-09 ((6)~(10)). That is, debtors adjusted their consumption growth down more conspicuously during the less adverse macroeconomic environment (2011-13) than during the recession (2007-09). This result suggests the possibility that household balance sheets were more vulnerable in the interim period (2007-11) such that borrowers showed more sensitive responses even against the less adverse economic conditions in the latter period.[10] We find that all of the changes in disposable income, net worth, and family size have positive signs with high significance levels, as expected, consistent with the findings of previous studies. We also note that households with older householders above 60 years of age show lower levels of consumption growth compared to those in other age groups for 2007-09, suggesting that older household heads behaved in a more precautionary manner under the mounting uncertainty associated with the global financial crisis of 2007-09.[11] It is interesting to note that household heads with higher educational

[10]Household debt increased by almost 40% from 2007 to 2011, largely led by loans from non-bank financial institutions. See Kim and Yoo (2013) and Kim and Byun (2012), among others, for detailed information about how household debt and its quality levels changed during the period.

[11]The regression for the robustness check shows that consumption growth for older householders during

attainment have shown lower consumption growth in the face of the adverse economic conditions in both 2007-09 and 2011-13 periods.

It is important to note that both the debt dummy (β_1) and the cross-product term between the debt dummy and the debt-to-asset ratio (β_2) are highly significant ((4), (5), (9), and (10)) such that omitting either of them can lead to biased estimates. In order to gain a sense of the size of the impact of indebtedness on consumption growth during 2007-09, we can examine the estimates of the debt dummy (-0.073) and the cross-product term between the debt dummy and the debt-to-asset ratio (-0.07) in (4). If we considered a debtor with a 10% debt-to-asset ratio and a non-debtor, the difference in their nominal consumption growth rates with all else being equal would be -8%p/2yrs. (=-0.073-0.07*0.1), or -4%p/yr. On the other hand, if we considered the case between debtors with a 10%p difference in the debt-to-asset ratio, the difference in their nominal consumption growth rates would be -0.7%p/2yrs. (=-0.07*0.1), or -0.35%p/yr. Following the same procedures above and based on estimation results in (9) for the period of 2011-13, we note that the difference in the nominal consumption growth rates between the debtor with a 10% debt-to-asset ratio and the non-debtor would be -10.96%p/2yrs. (=-0.098-0.116*0.1), or -5.48%p/yr. On the other hand, the difference in nominal consumption growth rates between debtors with a 10%p difference in the debt-to-asset ratio would be -1.16%p/2yrs. (=-0.116*0.1), or -0.58%p/yr. in 2011-13. Hence, there appears to be a relatively large difference between debtors and non-debtors in terms of their consumption behavior in the face of adverse economic conditions in comparison with the difference between debtors with different leverage ratios.

We find from the above analyses that higher leverage ratios may exert greater downward pressure on the growth rates of consumption expenditures. Figure 7 shows the heterogeneity in the household leverage ratios in terms of the debt-to-

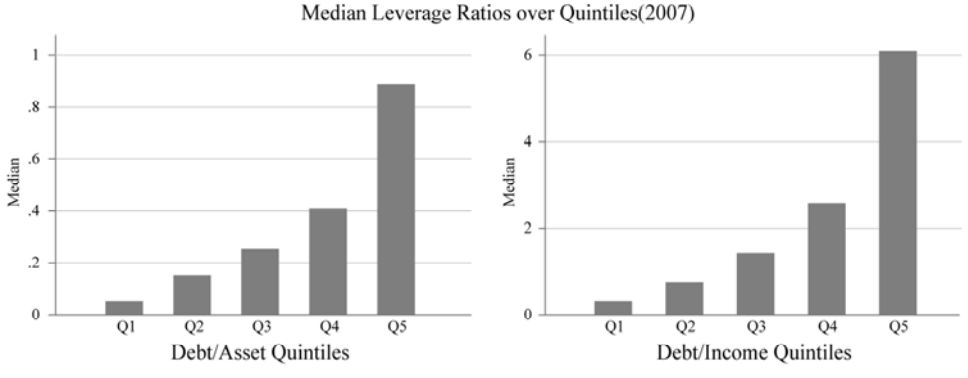

FIGURE 7. LEVERAGE RATIOS OF INDEBTED HOUSEHOLDS: DEBT/ASSET AND DEBT/INCOME RATIOS

Note: The leverage ratios are divided into five quintiles from the bottom 20% to the top 20% (Q1, Q2, Q3, Q4, and Q5).

2011-13 would also be lower than that of other age groups if the possible previous consumption spikes were controlled for by including the lagged consumption growth in the regression specification.

TABLE 3—REGRESSIONS EXPLAINING CONSUMPTION GROWTH: DURABLES VS. NON-DURABLES

	△Consumption in 2007-09				△Consumption in 2011-13			
	(Durables)		(Non-durables)		(Durables)		(Non-durables)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
D_dum[a]	-0.505**	-0.452**	0.041**	0.029*	-0.213**	-0.201**	-0.023*	-0.031**
	(0.121)	(0.121)	(0.015)	(0.015)	(0.072)	(0.072)	(0.014)	(0.014)
(D/A)*D_dum[a]	-0.198		-0.031		-0.232**		-0.038**	
	(0.151)		(0.019)		(0.100)		(0.019)	
(D/Y)*D_dum[a]		-0.050**		-0.000		-0.035**		-0.002
		(0.021)		(0.003)		(0.013)		(0.002)
△Income	0.139**	0.156**	0.075**	0.076**	0.257**	0.277**	0.094**	0.096**
	(0.066)	(0.066)	(0.008)	(0.009)	(0.043)	(0.043)	(0.008)	(0.008)
ΔNet Worth	0.028**	0.022*	0.005**	0.003**	0.017*	0.009	0.006**	0.005**
	(0.013)	(0.012)	(0.002)	(0.002)	(0.010)	(0.009)	(0.002)	(0.002)
ΔFamily Size	0.229**	0.232**	0.185**	0.185**	0.305**	0.307**	0.194**	0.194**
	(0.091)	(0.091)	(0.012)	(0.012)	(0.050)	(0.050)	(0.010)	(0.010)
(40s_50s)_dum[a]	0.387**	0.415**	-0.046**	-0.044**	0.154*	0.175**	-0.020	-0.017
	(0.133)	(0.133)	(0.017)	(0.017)	(0.088)	(0.088)	(0.017)	(0.017)
(After_60)_dum[a]	0.315*	0.371**	-0.103**	-0.101**	-0.137	-0.085	0.015	0.02
	(0.172)	(0.172)	(0.022)	(0.022)	(0.107)	(0.107)	(0.020)	(0.020)
Education[a]	0.021	0.029	-0.011**	-0.010**	-0.034	-0.029	-0.013**	-0.013**
	(0.038)	(0.038)	(0.005)	(0.005)	(0.024)	(0.024)	(0.005)	(0.005)
Const.	3.236**	3.167**	0.190**	0.185**	0.304**	0.250*	0.063**	0.057**
	(0.227)	(0.226)	(0.029)	(0.029)	(0.147)	(0.146)	(0.028)	(0.028)
Adj. R^2	0.012	0.013	0.101	0.100	0.029	0.029	0.148	0.147
# Obs.	3,791	3,791	3,791	3,791	4,236	4,236	4,236	4,236

Note: * p<0.1, ** p<0.05. [a] indicates the beginning of each period: 2007 for the sample period of 2007-09 and 2011 for the sample period of 2011-13. ΔIncome, ΔNet Worth, ΔFamily and Size are changes in income, net worth, and family size, respectively. D_dum is a dummy variable for debt holdings. D/A and D/Y are debt-to-asset and debt-to-income ratios, respectively. (40s_50s)_dum and (After_60)_dum are dummy variables denoting a householder aged 40-60 and after 60 respectively.

asset ratio and the debt-to-income ratio. In particular, we find that debtors in the top quintile take very high leverage positions compared to those by other groups. This distributional feature suggests that the impact of the leverage ratio on household spending is heterogeneous, with its impacts more concentrated in highly leveraged households. We can compute the difference in the depressive effects of leverage ratios on consumption growth across different groups of leverage ratios. For example, the difference in the median debt/asset ratio between the fourth and the fifth quintile is approximately 0.48 for 2007, explaining approximately -3.36%p/2yrs. (=-0.07*0.48), or a -1.68%p/yr. difference between the two groups for nominal consumption growth during 2007-09. The difference in the median debt/asset ratio between the third and fourth quintile is close to 0.16 for 2007, explaining about -1.12%p/2yrs. (=-0.07*0.16), or a -0.56%p/yr. difference between the two groups in terms of nominal consumption growth for 2007-09. Thus, we note how the distributional feature of leverage ratios in the household sector would predict the distribution of consumption growth with all else being equal.

Table 3 shows the regression results for consumer durables and non-durables in the two periods of 2007-09 and 2011-13. Household expenditures can be divided into durable goods and non-durables. The demand for consumer durables may be more sensitive to uncertainty and credit standards than that for non-durables; hence, the responses for durables may be more dramatic in times of more severe economic downturns. We find that indebted households cut back their demand for durables much more strongly than their demand for non-durables in the face of the

TABLE 4—REGRESSIONS EXPLAINING CONSUMPTION GROWTH:
FOR INDEBTED HOUSEHOLDS WITH DIFFERENT INCOME AND NET WORTH LEVELS

	△Consumption in 2007-09				△Consumption in 2011-13			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(D/A) [a]	-0.169**	-0.139**			-0.179**	-0.189**		
	(0.057)	(0.044)			(0.071)	(0.046)		
(D/A)*(50<Y<80)_dum[a]	0.036				-0.062			
	(0.079)				(0.089)			
(D/A)*(Y>80)_dum[a]	-0.013				0.010			
	(0.095)				(0.104)			
(D/A)*(50<NW<80)_dum[a]		-0.612**				-0.607**		
		(0.152)				(0.147)		
(D/A)*(NW>80)_dum[a]		-1.111**				-1.095**		
		(0.243)				(0.218)		
(D/Y) [a]			-0.017*	-0.017**			-0.032**	-0.020**
			(0.009)	(0.007)			(0.008)	(0.006)
(D/Y)*(50<Y<80)_dum[a]			-0.004				-0.004	
			(0.012)				(0.012)	
(D/Y)*(Y>80)_dum[a]			-0.015				0.001	
			(0.013)				(0.011)	
(D/Y)*(50<NW<80)_dum[a]				-0.012				-0.059**
				(0.012)				(0.012)
(D/Y)*(NW>80)_dum[a]				-0.038**				-0.045**
				(0.017)				(0.018)
Adj. R^2	0.040	0.056	0.042	0.044	0.064	0.081	0.071	0.082
# Obs.	1,868	1,868	1,868	1,868	1,894	1,894	1,894	1,894

Note: * p<0.1, ** p<0.05, [a] indicates the beginning of each period: 2007 for the sample period of 2007-09 and 2011 for the sample period of 2011-13. All explanatory variables are not reported to save space. D/A and D/Y are debt-to-asset and debt-to-income ratios, respectively. (50<Y<80)_dum and (Y>80)_dum are dummy variables for households' disposable income levels between 50-80% and above 80%, respectively. (50<NW<80)_dum and (NW>80)_dum are dummy variables for households' net worth levels between 50-80% and above 80%, respectively.

adverse economic environments, thus confirming the argument of Mishkin (1976) based on household-level analysis. In 2007-09, indebted households' levels of demand for durables showed much lower growth rates than that for non-debtors ((1) and (2)), while their expenditures for non-durables recorded somewhat higher growth rates than those of non-debtors ((3) and (4)). In 2011-13, debtors adjusted their expenditure growth down for both durables and non-durables, while their downward adjustments were much stronger for durables ((5) and (6)) than for non-durables ((7) and (8)). The decline in consumption growth for non-durables in particular may reflect the fact that debtors' perceptions of economic prospects may have been worse. Regarding the nominal growth in non-durable consumption in 2011-13, the difference between a debtor with a 10% debt/asset ratio and non-debtors would be -2.68%p/2yrs. (=-0.023-0.038*0.1), or -1.34%p/yr., while the difference between debtors with a 10%p difference in the debt/asset ratio would be -0.38%p/2yrs, or -0.19%p/yr.

Table 4 shows the regression results for indebted households with different income and net worth levels. Household income is divided into three groups: below the median (<50%), 50-80%, and above 80%. Household net worth levels are also divided into three groups: below the median (<50%), 50-80%, and above 80%. Families with low income (wealth) levels are likely to be liquidity-constrained, whereas families with high income (wealth) levels tend to be not or less liquidity-constrained with high saving rates. We compare low-income (wealth) indebted

households with high-income (wealth) groups to shed light on the roles of uncertainty and credit standards. The estimation results show that household leverages in all income (wealth) brackets exert significant downward pressure on consumption growth in both periods, while the effects are stronger in the high-income (wealth) groups. This result suggests that uncertainty or pessimistic views of the future may have caused leveraged households to adjust their consumption growth down in a more precautionary manner. The depressive effects of the leverage ratios on consumption growth are weaker in the low-income (wealth) brackets because they may have already spent a large share of their income for consumption to maintain their minimal living standards, while those in the top income (wealth) brackets still had room to reduce their spending. Given that leverage ratios tend to be higher in low-income households, the adverse events for low-income debtors may have had somewhat sizable effects on their spending growth despite the fact that the depressive effects of leverage on consumption growth are less severe for low-income groups than for high-income groups. It should also be noted that the depressive effects of leverage on consumption growth were greater in 2011-2013 ((5)~(8)) than in 2009-11 ((1)~(4)) in all income (wealth) brackets. This result suggests that household leverage may have raised more concern about the real economy in more recent years.

We also performed robustness-check regressions in the current study, though the estimation results are not reported here due to space constraints. We assessed how certain possible consumption spikes in previous years would affect the main results in the above analyses, finding that the regressions for the robustness check increase R^2 significantly, while most of the main results of this paper remain effective.[12] In addition, we checked how debt accumulation for a temporarily large expenditure in the previous period would affect the estimated relationship between ex-ante leverage and ex-post consumption growth, finding that the regressions excluding those (potentially bias-generating) households from the sample still support the main results of the current study.[13]

VII. Concluding Remarks

The findings of the current study show that the soundness of household balance sheets matter in the real economy even in cases in which financial markets and intermediaries continue to function without severe disruptions. In other words, liability-side vulnerability or the weak financial positions of households may put

[12]For the robustness check, we controlled several possible spikes in consumption, such as auto purchases at the beginning year (t_0) by including the lagged consumption growth in the regression specifications, as discussed by Andersen *et al.* (2014) and Son and Choi (2015). Among previous studies, Andersen *et al.* (2014) and Son and Choi (2015) considered the effects of such possible consumption spikes on the subsequent consumption growth, whereas Dynan (2012) did not take such effects into account in her analyses.

[13]Households that increased their debt for temporarily large expenditures (such as medical expenditures or auto purchases) in the previous period may contribute to some bias to the estimated relationship between ex-ante leverage and ex-post consumption growth. In order to deal with this issue, we undertook robustness-check regressions while excluding from the sample the (potentially bias-generating) households that spent more than their available income and increased their debt during the previous period. We find that the main arguments of the current study remain effective even after controlling for this type of potential bias.

downward pressure on private consumption even when the economy does not undergo a dramatically deep downturn. It should be noted that the depressive effects of households' obligations on consumer spending may be heterogeneous, while they are more concentrated for highly leveraged groups than they are for others. That is, consumption expenditures of highly leveraged households may be more vulnerable to shocks than those of low-leveraged households or non-debtors. We find that adjustments in consumer spending by debtors were stronger for durable goods than for non-durables. In addition, we find that debtors in high-income (wealth) groups showed even stronger adjustments in their consumption expenditures than did low-income (wealth) groups. These findings suggest that leveraged households may have behaved in a more precautionary manner in the face of uncertainty or pessimistic economic prospects, hence contributing to weak consumption growth. The above findings suggest that keeping household balance sheets sound may be important for the resilience of the real economy.

In the following paragraphs, we discuss several policy issues with respect to the depressive effects of liability-side household vulnerability on consumption. In order to keep the economy resilient, the weakening demand from leveraged households should be offset by rising levels of demand from other sectors of the economy. However, friction existing in many areas of the economy may prevent the reallocation of resources from one sector to another, aggravating the downward pressure on aggregate demand levels and on the overall economic activity, as indicated by Eggertsson and Krugman (2012), Hall (2011) and by Midrigan and Philippon (2011), among others. Thus, there may be room for policies to cushion the weakness on the demand side by relieving households' debt burdens or by creating some demand.

Policies to improve balance sheets may contribute to the recovery of the household sector, as balance sheet deterioration due to excessive debt accumulation may depress consumer spending. In the face of a debt-driven slow-down, monetary policies which raise inflation expectations may contribute to reducing real debt burdens (Svensson 2012). However, the central bank's credibility may be a factor affecting inflation expectations; it can be argued that central banks may have difficulty in raising inflation expectations owing to their apparent commitment to prevent it (Eggertsson and Krugman 2012). Hence, it is often argued that fiscal policies may play a more effective role in getting the economy out of a debt-driven slow-down if vulnerable balance sheets can be repaired in a relatively short period of time without damaging fiscal consolidation (Eggertsson and Krugman 2012). However, it should be noted that there still appears to be unsettled debate regarding the effectiveness of fiscal policies.

Monetary and financial policies in the past and in the present can affect the cost and availability of credit such that households may be incentivized to accumulate large amounts of household debt. If household balance sheets deteriorate, they would depress future consumer expenditures, such as those on durable goods, and house purchases in particular, because leveraged households may fear or are more likely to experience financial distress, as argued by Mishkin (1976, 1977, 1978). In this respect, there may be an emerging role for macro-prudential policies that attempt to prevent rapid credit expansions or too much leverage in order to keep households' balance sheets sound, for example.

From an institutional perspective over a much longer time horizon, we can examine institutional arrangements that may affect the cost and availability of credit, as misaligned incentives may weaken the financial positions of households as well as financial institutions. In other words, current institutional arrangements may need to be under scrutiny regarding their appropriateness in relation to their overall economic performance. For example, the cost of defaults may be strongly associated with households' consumption behaviors, especially in times of rising uncertainty followed by pessimistic views of the future economy, as argued by Olney (1999).

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Korea's Participation in Global Value Chains: Measures and Implications

By SUNGHOON CHUNG*

This paper measures the extent to which South Korea participated in global value chains (GVCs) from 1995 through 2011 and scrutinizes the consequences of such participation on the Korean economy. To this end, the World Input Output Database is utilized to calculate GVC income, GVC employment, and value-added exports created by Korean and foreign industries. Our findings show that Korea radically internationalized its production activities during the sample period, widening the gap between gross exports and value-added exports. We also document that Korea's participation in GVCs has changed the value-added and employment structures in domestic industries in accordance with their comparative advantages while exacerbating the degree of wage inequality.

Key Word: Global Value Chain, GVC, Trade in Value Added, GVC Income, GVC Employment, International Fragmentation of Production
JEL Code: F10, F21, F23

I. Introduction

The global value chain (hereafter, GVC) refers to the chain-like structure of a product's value-added characteristics across countries resulting from the division of the production sequence on a global scale. Although such international fragmentation has long been practiced, it has recently drawn significant attention from both researchers and policymakers, as technological advancements along with ever-lower trade barriers has made it much more active and complex.

In a seminal paper, Hummels *et al*. (2001) first developed a measure of imported intermediate goods' share of exports, also known as vertical specialization (VS), finding that the VS share of 14 major countries' exports was approximately 21% in 1990. They also document that the share increased by almost 30% over the ensuing two decades. As a more recent and intuitive example, Linden *et al*. (2009) dissect

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the iPod, valued at US $300, finding that China, the final iPod exporting country, contributes only about $5 to the total value through assembly and inspection steps. Meanwhile, Japan earns $27 for each iPod, though not by exporting it directly but by providing core parts and components.

Thus, it is recognized that using gross output or exports may not be appropriate to gauge the value of the production activities conducted in each country. Indeed, a burgeoning amount of literature introduces alternative measures and analyses based on the GVC perspective to better explain what a country does and how much value it adds (See Daudin *et al*. (2011), Johnson and Noguera (2012), Timmer *et al*. (2013, 2014), Koopman *et al*. (2014), Baldwin and Lopez-Gonzalez (2015) among others). These papers usually apply their measures to cross-country comparison analyses, but not to a particular country.

The main purpose of the present paper is to provide a broad picture of the level as well as the change in Korea's position in this integrated world through GVCs. Not only for policy implications, studying the Korean experience is interesting, as Korea is representative of small open economies that rely largely on trade. In particular, it has been involved in global supply chains since the 1960s as a core strategy for its economic growth. Despite this long history, we are deficient in the relevant statistics on how much Korea has engaged in the vertical linkages across countries and what the consequences of such engagement are.

Applying the method suggested by Johnson and Noguera (2012) and Timmer *et al*. (2013) and using the World Input Output Database (WIOD), this paper specifically calculates three GVC-related measures: value-added exports, GVC income and GVC employment. We then use these measures to gauge the degree of participation by Korean industries in GVCs during the sample period from 1995 to 2011. Furthermore, we analyze the compositional changes in value-added aspects and employment in the Korean manufacturing industry due to GVC participation.

Our finding indicates that Korea is one of the most active countries in terms of GVC participation among 40 countries. While gross exports had grown, allowing Korea to become the seventh largest exporter by 2011, its growth of value-added exports, i.e., the domestic value-added created by foreign countries, lagged, widening the gap between the two figures. In fact, the ratio of value-added exports to gross exports, or the VAX ratio, fell continuously from 75% in 1995 to 59% in 2011. Moreover, the VAX ratios are the lowest among the top exporting industries, such as the petro-chemical, transport equipment, and electronic equipment industries. These findings suggest that value-added exports can be an alternative measure of the competitiveness of Korean industries in the global market, especially when one is more interested in production activities as opposed to transacted products.

We also find that Korea's active participation in GVCs induced substantial changes in its industrial structure in terms of both value-added and employment aspects over the sample period. Specifically, 25% of the value added in Korean manufactured final goods ultimately went to foreign countries in 1995, but the foreign share increased to 38% in 2011. In terms of employment, approximately 51% of all employees were found to be non-nationals who worked in relation to the production of the same Korean manufactured final goods, but this foreign share increased further to 60% in 2008. During this period, a critical number of middle-

and high-skilled foreign workers were substituted for low- and middle-skilled domestic workers, potentially exacerbating wage inequality in Korea. Korean manufacturers, as suppliers of intermediate products, also enlarged their role in foreign GVCs throughout the same period; the share of manufacturing GDP created by participating in foreign GVCs increased from 26% in 1995 to 42% in 2011, and the share of employment increased from 26% in 1995 to 37% in 2008.

This paper contributes to the literature in three ways. First, we provide a useful analytical framework with which to measure Korean industries' global competitiveness, overall structure, and its changing patterns in the GVC world. The complicated real world is well summarized in our two-country, three-sector framework, providing a clear picture and thus informative statistics on the value chain structure between domestic and foreign industries.[1]

Second, our study complements prior studies of the internationalization of production activities using micro-level data by providing aggregate changes and related implications. Although micro-based studies have advantages when used to identify the causal effect of internationalization on domestic economies, they typically lack aggregate consequences. For example, Ahn (2006) and Park (2009) estimate the causal, marginal effect of offshoring on domestic employment, but these studies are limited in terms of how they identify the numbers of domestic workers lost or gained as a result of offshoring.

Third, by exploiting world input-output tables (WIOTs), our study provides useful information that cannot be obtained by analyzing domestic input-output (IO) tables. For example, WIOTs allow us to calculate the contribution of each foreign country to the total GDP in Korea, whereas domestic IO tables cannot provide such information. All analyses of structural changes in Korean industries are only possible with WIOTs.

The remaining sections are organized as follows. Section II provides an illustrative example to define the three measures related to GVC and introduces the data used in the paper. Section III contrasts statistics based on value-added exports and those pertaining to gross exports to measure the degree to which Korea has participated in GVCs. It also highlights the recent trend of international competitiveness in Korean industries. Section IV narrows our focus to the Korean manufacturing industry to show its pattern of structural changes in the composition of value-added and employment using GVC income and GVC employment. Section V concludes with policy implications.

[1]In a spirit similar to ours, Kim *et al.* (2014) and Yoon (2015) measure the competitiveness and value-added structure of Korean exports, respectively, using the decomposition method of Wang *et al.* (2013). Our analyses deal with not only exports but also with the production structures of Korean industries.

II. Concepts and Measurement of GVCs

A. *An Illustrative Example*

In this section, we introduce three measures to evaluate Korea's participation and activity in GVCs: GVC income, GVC employment, and value-added exports. The first two measures come from Timmer *et al.* (2013, 2014), and the last one was originally developed by Johnson and Noguera (2012). For formal definitions and detailed derivations of each measure, readers can refer to the Appendix or to the original papers. Here, we start with a simple example to illustrate the concepts intuitively.

Suppose there is a firm that produces diamond rings in country B (country B refers to the home country). This firm does not mine rough diamonds (intermediate good 1) itself but it imports them from country A for $10 per unit. In addition, shanks (the band part of a ring) (intermediate good 2) are procured from a domestic shank-producing firm at $3 per unit. The firm producing diamond rings in country B processes the imported rough diamonds and combines them with the shanks to sell in the global market. Figure 1 illustrates this diamond ring GVC structure.

The processing of rough diamonds and the assembly of ring parts require labor and capital inputs, and their value added in unit terms is $4 and $2, respectively. Finally, the diamond ring production firm pays $1 for insurance (intermediate good 3) provided by an insurance company in country C in order to provide buyers with a one-year warranty service for any defective or damaged products. Therefore, the final price of one diamond ring (final good) is $20, i.e., the sum of the prices of the intermediate goods ($10+$3+$1) and the value-added of labor and capital inputs ($4+$2).[2]

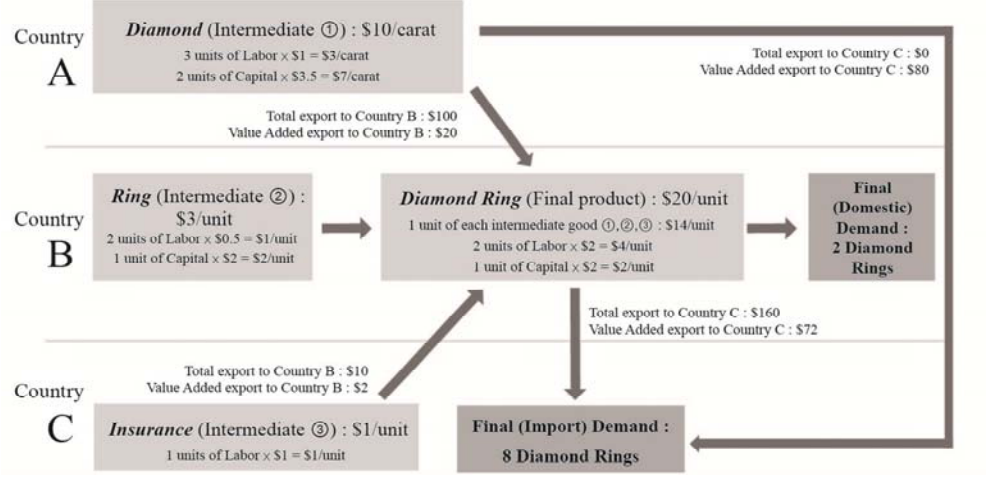

FIGURE 1. GVC OF DIAMOND RINGS

[2]We assume an absence of a retail margin and transport expenses in this example. In reality, these factors are included in the value-added of the final producers (the diamond-ring-producing firm in country B in this example).

TABLE 1—ALLOCATION OF INCOME, EMPLOYMENT IN THE DIAMOND RING GVC

Cnty	Industry (Product)	GVC Income	GVC Employment	GVC Capital	Labor Income	Capital Income	Value-added Export	Gross Export
A	Diamond	100	3	2	3×1×10=30	2×3.5×10=70	B:10×2=20 C:10×8=80	B:10×10=100 C: 0
B	Ring	30	2	1	2×0.5×10=10	1×2×10=20	C:3×8=24	C: 0
	Diamond	60	2	1	2×2×10=40	1×2×10=20	C:6×8=48	C:20×8=160
	Ring							
C	Insurance	10	1	0	1×1×10=10	0	B:1×2=2	B:1×10=10
Total		200	8	4	90	110	174	270

If two diamond rings are bought in country B (domestic market) and eight diamond rings are purchased in country C, the final demand for the diamond rings is 10. Thus, the total output must be \$20×10=\$200. The realized value-added of each industry in each country is shown in Table 1. As a result of this production sequence organized by the diamond ring firm of country B, country A gains \$100 of added value by mining rough diamonds, and by producing shanks and manufacturing diamond rings, country B gains added value of \$30 and \$60, respectively. Country C gains \$10 of added value by providing the insurance service.

As shown in the example of the production of diamond rings, we define global value chains as a fragmented sequence of production along with its corresponding value-added structure across countries and industries. The created value-added component in each industry of each country is termed the global value chain income (GVC income). The sum of GVC income is, hence, equal to the total output (=total expenditure).

Among the participants in this GVC, the diamond-ring-producing firm of country B, or the final producer, makes decisions about whether to produce or outsource the intermediate goods and from where to outsource once decided. Thus, it serves as an organizer of the GVC.[3] All other firms participate in the GVC as intermediate goods suppliers.

Meanwhile, the gross domestic products (GDPs) of countries A, B, and C are \$100, \$90, and \$10, respectively, as they are expressed as the sum of GVC income within each country. Note that the GVC income of country B (=GDP of country B) accounts only for 45 percent of the total output, while the GDP of country A accounts for 50 percent of the total output. In other words, despite the fact that country B is the final producer and exporter of diamond rings, country A receives the most income from the diamond ring GVC structure.

If we know the types and amounts of input used in the production process for each country and industry participating in the GVC along with the created value-added component, we can also calculate how much each factor of production indeed creates with regard to added value. As shown in Figure 1, the final producer in country B generates \$4 and \$2 of added value from two units of labor and one unit of capital, respectively, for each diamond ring. It is also possible to determine the amounts of labor and capital which are injected to produce each of the

[3]Final producer is not necessarily an organizer in all GVCs.

intermediate goods in the production of a diamond ring (the final good), as shown in columns (4) and (5) in Table 1. In particular, each country and industry-specific labor input required for the production of the final good is defined as the global value chain employment (GVC employment). The total final demand of ten diamond rings creates GVC employment of 30 units in country A, 40 units in country B, and 10 units in country C.

Summarizing the illustration thus far, the formation of a GVC means the participation of various industries (or firms) of different countries in the intricate and segmented stages of production, and the generated value-added and labor input within such a network are defined as GVC income and GVC employment, respectively. GVC income and GVC employment are not directly observed in unprocessed data. Instead, it is possible to calculate these factors with certain assumptions as to the appropriate data. The calculation method is introduced in the next section. Through the GVC analysis, we obtain a clear sense of how the total output of $200 is allocated across countries and industries.

Meanwhile, value-added exports shown in column (6) refer to the amount of added value demanded by the foreign final consumers. According to Figure 1, the final consumers of the ten diamond rings are country B (two rings) and country C (eight rings). Thus, out of the total value-added exports of $100 by country A, $20 goes to country B and $80 to country C. Country B, by producing shanks and manufacturing diamond rings, exports value-added of $24 and $48, respectively, to country C. Likewise, country C exports a value-added of $2 to country B, which demands two rings. The total value-added exports of $174 and the sales in the domestic markets of country B (=$18) and country C (=$8) add up to $200, which is the total GVC income (=total output).

It is important to note the difference between value-added exports and conventional gross exports tallied for each country, even with identical transactions. The gross exports of country B to country C is $160, which is the price of eight diamond rings. However, the value-added exports in country B is only $72. The remaining $88 is the sum of the intermediate goods prices imported by countries A and C, and it is already accounted for in their exports to country B. Moreover, $8 of insurance exported from country C is then re-imported and domestically consumed, causing a double-counting problem. In other words, 88+8=$96 has also been recorded to make the world's gross exports $270. Due to this double-counting problem, country B's gross export level leaves room for overestimating the income of country B.

Another noticeable difference between value-added exports and gross exports is shown in the case of country A. Although country A transacts only with country B, 80 percent of the created value-added by the mining of rough diamonds is ultimately consumed in country C, causing a large discrepancy between the two export measures for country A. At first glance, country A's major trade partner appears to be country B, but its trade performance is actually more affected by the economic situation of country C, where the majority of diamond ring buyers are located. The key aspect of value-added exports is that it splits each country's gross output according to the destination in which it is ultimately absorbed in the form of final demand.

B. *World Input-Output Table*

In order to calculate GVC income, GVC employment, and value-added exports for the actual economy, we use world input-output tables (WIOTs). The World Input Output Database (WIOD) project has developed WIOTs for forty-one countries, including 27 EU members and what is referred to as the rest-of-the-world (ROW), covering the period from 1995 to 2011. The tables connect the trade flows of intermediate and final goods across countries and industries. NACE Rev. 1 provided by the EU is used to classify 35 industries, among which 14 belong in the manufacturing sector.[4] A thorough description of the methods and original sources of information used for the construction of the WIOTs is available in Timmer (2012).

In fact, several leading international organizations and research institutes also provide data similar to WIOT, each of them having its own advantages and disadvantages. The reasons for using the data constructed by WIOD are as follows: (i) WIOT provides more industries and countries relative to other published data sources, and (ii) WIOTs are available for every year from 1995 to 2011, while other institutions provide tables for only a few years (e.g., every five years). Of course, a national input-output table is required every year in order to develop WIOT on a yearly basis. If this is not available, additional assumptions such as an invariable input-output structure are needed to create it.

One fact that should be mentioned at this point is that there always exists statistical discrepancies in IO tables, and there is no means by which clearly to identify the more accurate instances among them. This also applies to the WIOT used in this study. Therefore, rather than having absolute confidence in the statistical figures calculated from the WIOTs, we place more emphasis on understanding trends and relative statuses by means of time series analyses and cross-section comparisons.

The WIOD also provides information such as national input-output tables (NIOTs) and what are termed socio-economic accounts (SEAs) at the industry level. In particular, SEAs contain data on output, value-added, capital stock, and employment factors according to three skill type (i.e., the low, middle, high skill types) that are needed to measure the contribution of each production factor to economic growth, also known as growth accounting, for the 40 sample countries.[5] We use this data in section 4 to determine whether GVC participation leads to changes in the input structure of production factors.

[4]The term NACE is derived from the French *Nomenclature statistique des Activités économiques dans la Communauté Européenne*. See also Table A1 and Table A2 in the Appendix for industry classification and sample countries in the WIOT, respectively.

[5]The data here are constructed in the same manner used by the EU KLEMS database, a database frequently used in growth accounting exercises.

III. Value-Added Exports in Korea

A. *Indicator of Korea's participation in GVCs*

In this section, we present evidence of how active Korea's GVC participation was from 1995 to 2011 by comparing value-added exports and gross exports. This analysis calls for a reevaluation of the international competitiveness of Korean industries based on value-added exports, which we undertake at the end of the section.

As the first comparison, Figure 2 shows the time trends of Korea's export share of the world's exports based on gross exports and value-added exports. For gross exports, the share starts at 2.7% in 1995 and increases to 3.3% in 2011, when Korea became the seventh largest exporting country in the world. However, the value-added export share more or less stagnated over the sample period, widening the gap between the two trends.

Table 2 presents the VAX ratio across the major countries defined in the previous section. When gross exports are assumed to be $100, the VAX ratio of Korea is $75 (3/4) for 1995 but then drops to $59 in 2011. The downward trend in the VAX ratio (by 21.7%) is much greater than that of other major countries, including manufacturing-based economies such as Germany and Japan. The sharp and sudden drop in the VAX ratio indicates that Korea was incorporated into the GVC more rapidly compared to other countries.[6]

Meanwhile, because value-added content of exports (VAX) is the GDP created

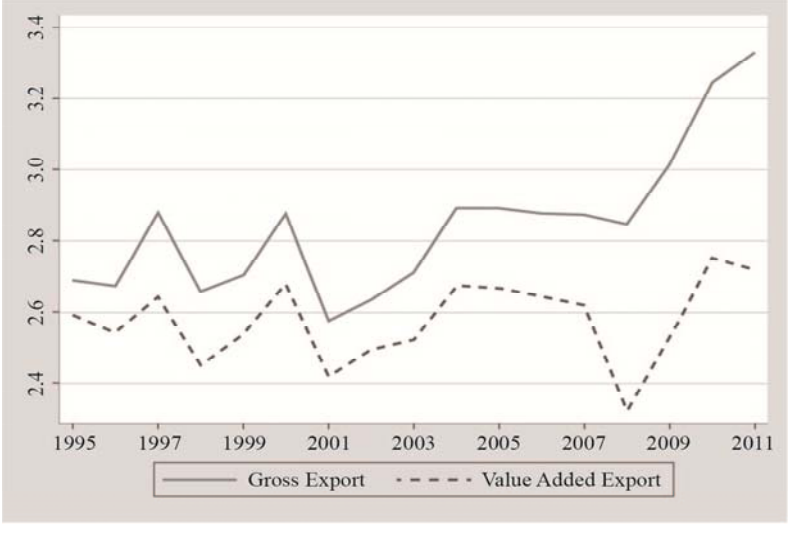

FIGURE 2. RATIO OF KOREA'S EXPORTS TO WORLD EXPORTS

Source: World Input-Output Database (WIOD) and the author's calculations.

[6]We discuss the implications of the rapid GVC participation of Korean industries in Section 4A.

TABLE 2—TIME TRENDS OF THE VAX RATIO BY COUNTRY

Year	1995	2000	2005	2011	Growth Rate (%)
Korea	0.75	0.70	0.67	0.59	-21.7
Japan	0.92	0.9	0.86	0.81	-11.3
China	0.84	0.82	0.72	0.75	-9.7
Taiwan	0.67	0.63	0.56	0.52	-21.6
Germany	0.79	0.74	0.72	0.69	-12.6
USA	0.83	0.78	0.78	0.79	-4.3

Source: World Input-Output Database (WIOD) and the author's calculations.

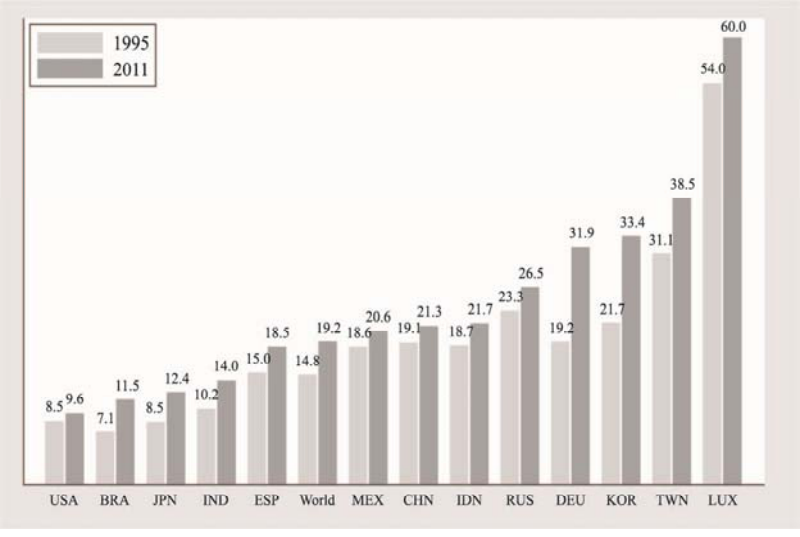

FIGURE 3. RATIO OF VALUE-ADDED EXPORT TO THE COUNTRY'S GDP

Source: World Input-Output Database (WIOD) and the author's calculations.

by foreign demand for the domestically produced goods and services, the rising level of VAX within a country can be interpreted as its GDP having a growing dependence on foreign markets. When value-added exports are calculated at the country level, the contribution of each foreign country to Korea's GDP becomes known. This could not be estimated prior to the creation of WIOTs.

In that sense, Figure 3 shows the share of value-added exports to the country's GDP. The Korean share of 33.4% in 2011 indicates that approximately one-third of Korea's GDP is generated by the final demand from other countries. When considering the world average of 19.2%, Korea's reliance on overseas markets is quite high, and its growth rate from 1995 (53.6%) is also among the highest compared to those of other countries in the WIOD data. Of course, this is another indication of Korea's rapid involvement in the global market.

It can be meaningful to identify the largest foreign consumer of Korean value-added goods, and this is what Table 3 shows. Specifically, Table 3 compares value-added exports with gross exports in 1995 and 2011 for four major partner countries.

TABLE 3—EXPORTS TO MAJOR CONSUMERS OF KOREAN PRODUCTS

	1995			2011		
	Value-added export	Gross Export	Difference (%p)	Value-added export	Gross Export	Difference (%p)
Subtotal	62.9	60.5	2.4	58.6	59.4	-0.9
China	7.2	9.3	-2.1	20.4	25.7	-5.3
EU	17.7	14.9	2.8	17.2	14.7	2.5
USA	22.1	20.1	2.1	13.4	9.5	3.8
Japan	15.9	16.3	-0.4	7.6	9.4	-1.8
Other	37.1	39.5	-2.3	41.4	40.6	0.8
Total	100	100		100	100	

Source: World Input-Output Database (WIOD) and the author's calculations.

When examining total exports to these four countries, the value-added exports and gross exports both decreased by about 4% (62.9%→58.6%) and 1% (60.5% →59.4%), respectively, showing no significant difference between the two years.

However, we observe a large change between 1995 and 2011 when investigating the composition for each country/region; the largest export markets in order were the US, the EU, Japan and China in 1995, but the ranking changed to China, the EU, the US, and Japan by 2011. China's position on the list is particularly notable as its share of Korea's value-added exports surged from 7.2% in 1995 to 20.4% in 2011. Korea's dependence on the Chinese market can be accurately calculated by multiplying the dependence rate by the value-added export ratio, which was found to be 0.334×0.204×100 = 6.8%. In other words, nearly 7% of Korea's GDP is generated by China's final demand. Unlike China, the ratios were reduced in Japan and the US such that the sum of the two countries' ratios became similar to that of China alone. The dependence rates for the EU, US and Japan are 5.7%, 4.5% and 2.5%, respectively, and together with China, they amount to 20%, meaning that one-fifth of Korean GDP is generated by these three major trade partners.

Finally, we observe that in both 1995 and 2011, the gross export ratio is larger than the value-added export ratio in China and Japan. This may leave room for overstating China and Japan as consumers of domestic goods and services. The situation is reversed in the cases of US and EU, which both play a more significant role as consumers than would be expected in the gross export figures, as the gross export ratio is smaller than the value-added export ratio.

The dependence of domestic value-added on foreign demand may differ by industry. To check whether this is the case, Figure 4 shows the industry-specific shares of gross exports and value-added exports in the GDP for 2011. Indeed, the dependence on foreign markets differs significantly between the manufacturing and non-manufacturing industries. In particular, approximately two-thirds of the manufacturing value-added figure is attributed to foreign demand. Within the manufacturing industry, light industries such as food-processing, textiles and wood and paper show a relatively low dependence rate of around 30%, while electronics (78.3%) and transport equipment (76.6%) generate more than three-fourths of the total value-added figure from foreign demand. Hence, Korea's manufacturing industries, especially those on a large scale, can be significantly affected by worldwide business cycles due to their high dependence on foreign markets.

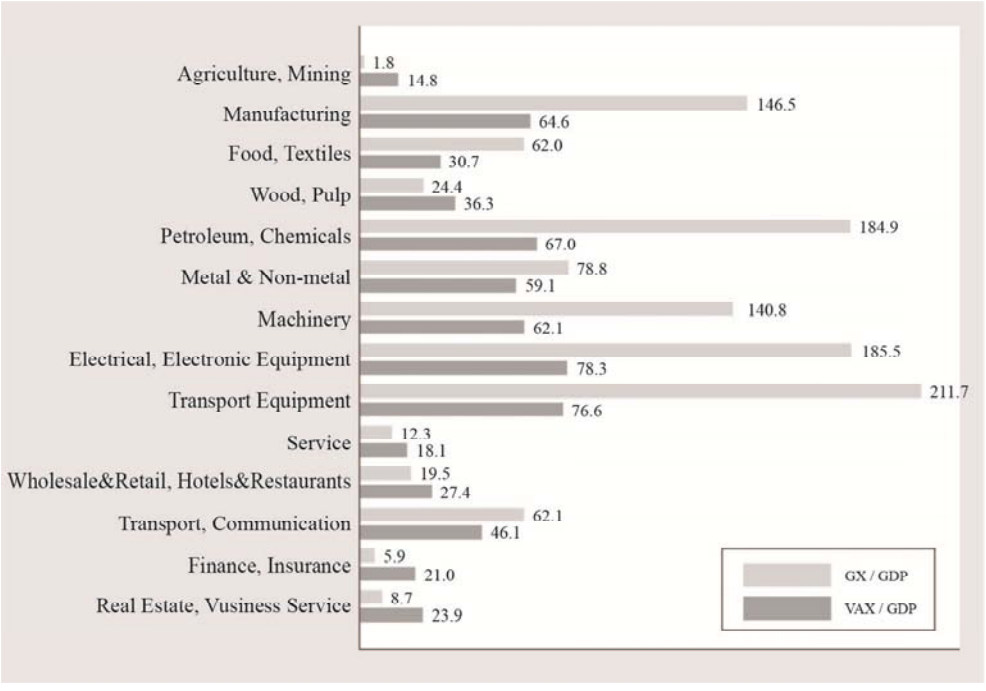

FIGURE 4. EXPORT SHARE IN GDP BY INDUSTRY

Source: World Input-Output Database (WIOD) and the author's calculations.

The ratio of gross exports to GDP for the entire manufacturing industry is 146.5%, and the ratio is highest in the transportation equipment industry given its export amount of more than twice the GDP (211.7%). The higher gross exports as compared to GDP stems from the fact that gross exports includes the value-added figures generated by (i) other domestic industries and by (ii) foreign industries within the GVC of transportation equipment. Thus, gross exports cannot tell us how much foreign purchases contribute to the industry's GDP, whereas value-added exports can serve as a suitable measure for this.

We can also calculate the industry-level VAX ratios using the information in Figure 4. For example, the VAX ratio of the transportation equipment industry is 76.6/211.7 = 0.36, the lowest among all industries. Although the ratio of gross exports to GDP is the largest among all industries, approximately two-thirds of its exports can be attributed to other domestic industries and foreign countries, reducing its contribution to GDP. For the same reason, we can easily witness a low VAX ratio in some of the leading export industries, such as the petro-chemistry, machinery, and electrical and electronic products industries. The VAX ratio for the entire manufacturing sector is 0.44. In the agriculture and service industries, the VAX ratios were found to be 8.06 and 1.47, respectively, meaning that value-added exports in those industries are greater than gross exports. The high VAX ratio in non-manufacturing sectors is easily understood because primary products and services are often inherent in exported manufacturing goods as intermediate inputs.

B. *International Competitiveness of Korean Industries*

Finally, we assess the international competitiveness of Korean industries based on their value-added exports. Thus far, gross exports have been widely used as a measure of international competitiveness. For example, the revealed comparative advantage (RCA) index suggested by Balassa (1965) is popularly used. The RCA is calculated as follows:

$$RCA_{ci} = \frac{GX_{ci} / \sum_i GX_{ci}}{\sum_c GX_{ci} / \sum_c \sum_i GX_{ci}} \quad (1)$$

The RCA index for industry *i* in country *c* is equal to the proportion of the gross exports of industry *i* in country *c* (GX_{ci}) within the country's gross exports (numerator) divided by the proportion of the world gross exports of industry *i* in the world's gross exports (denominator). If the numerator is larger than the denominator, country *c* can be said to have a comparative advantage in sector *i*.

However, because the figure for gross exports includes value-added factors generated by industries and countries other than industry *i* and country *c*, the RCA can misrepresent the true competitiveness of an industry. To give an example, many electronic products, such as the iPhone, are assembled and exported from China to countries all over the world. Though China is involved in a low value-added activity (assembly in this example), the amount of gross exports is high due to the high price of the iPhone, and so is the RCA index. Therefore, the RCA index measured in terms of gross exports is likely to overestimate the true competitiveness of the Chinese electrical and electronic products industry. Another important problem when using gross exports is that it is impossible to measure services that are inherently linked to the exported goods. Therefore, assessing the international competitiveness of the service industry using the RCA index is inappropriate.

Using value-added exports in the RCA calculation can circumvent these problems. Because only the value of the assembly process is factored into value-added exports, we can accurately measure the share of China in its export of electronic products. Moreover, because the exact value of the service provision is applied to the RCA calculation, it is possible to make a meaningful comparison of the service competitiveness between countries. This new equation for value-added RCA (VRCA) can be generated simply by replacing gross exports with value-added exports.

$$VRCA_{ci} = \frac{VAX_{ci} / \sum_i VAX_{ci}}{\sum_c VAX_{ci} / \sum_c \sum_i VAX_{ci}} \quad (2)$$

The VRCA index for each domestic industry is compared with the standard RCA index for the same industries in Figure 5. As presented in the figure, a considerable gap between VRCA and RCA is found in many industries, presenting different implications with regard to international competitiveness. For example, the metal and non-metal industry has been at a comparative disadvantage until recently

FIGURE 5. REVEALED COMPARATIVE ADVANTAGE BY INDUSTRY

Source: World Input-Output Database (WIOD) and the author's calculations.

according to the RCA index (RCA<1). However, the VRCA index shows that the metal and non-metal industries have a comparative advantage and that the level of the advantage has been rising. Korea's leading manufacturers, represented by

electric and electronic products and transportation equipment, have a comparative advantage according to both the RCA and VRCA indices, but VRCA is higher and increasing, thus diverging from RCA. The competitiveness of the two industries in generating added value in the foreign market (VRCA) can be said to be higher than what was implied by the standard index (RCA).

The overall change in the international competitiveness of the Korean manufacturing sector during the past 20 years can be observed in the first seven graphs in Figure 5. The competitiveness of the food-processing and textile industries has been dropping, while the competiveness of the wood and paper and the petro-chemistry industries was stagnant from 1995 to 2011. On the other hand, durable goods such as metals and non-metals, machinery, electrical and electronics goods, and transportation equipment have showed constantly enhanced competitiveness. What about the service industry? All of the service industries presented in the last five graphs in Figure 5 are found to have a comparative disadvantage or show weakening international competitiveness. Because the standard RCA indices for services may not correctly reflect the competitiveness of Korean services, we do not try to interpret them.

In sum, value-added exports provide useful information that gross exports cannot provide, as value-added exports focus on production activity rather than on products per se. Consequently, statistical indicators based on value-added exports can be used as alternative measures for evaluating the competitiveness of domestic activities in the international market.

IV. Structural Changes in the Korean Manufacturing Industry through its Participation in GVCs

As shown in the previous section, Korea's active participation in GVCs allows us to predict many changes in its compositional structure of industry-specific income and labor input. In this sense, this section analyzes the structural changes of GVC income and employment in the Korean manufacturing industry over the sample period. The reasons for focusing on the manufacturing industry are as follows: (1) GVC participation is the most vigorous in the manufacturing industry. (2) The flow of intermediate goods from the manufacturing to the non-manufacturing sector is much more frequent and intensive than the other way around.

We start by introducing the framework used for our analyses. Based on the mathematical exposition in Timmer *et al.* (2013) for calculating GVC income, we originally arrive at a 1435×1435 square matrix (41 countries multiplied by 35 industries).[7] Dealing with such a large matrix not only complicates the analysis but also makes it difficult to obtain the desired information. We thus aggregate countries into Korea (KOR) and the rest of the world (ROW) and industries into agriculture (AGR), manufacturing (MFC), and service (SVC) to formulate a two-

[7]See also Timmer *et al.* (2014) pp. 102~103 for an explanation of the GVC income matrix.

TABLE 4—TWO-COUNTRY, THREE-SECTOR GVC STRUCTURE

			The Final Producer (or product) of GVC						GDP/Emp. by industry
			KOR			ROW			
			AGR	MFG	SVC	AGR	MFG	SVC	
GVC Income / GVC Emp.	KOR	AGR							
		MFG							
		SVC							
	ROW	AGR							
		MFG							
		SVC							
Total Output / Total Emp.									World GDP/Emp.

country, three-sector matrix for GVC income.[8] The same matrix is also used for GVC employment by simply replacing the numbers in each cell.

The simplified GVC income structure is shown in Table 4. Recall the breakdown into an organizer and suppliers in a GVC based on their roles. Column titles in Table 4 indicate the organizers of GVCs, and row titles refer to the suppliers; there are six organizers and six suppliers in this two-country, three-sector world. We first examine the second column (6×1 cells), referring to GVC income (and GVC employment) created by the six suppliers participating in the domestic (i.e., Korean) manufacturing GVC. We then move to the second row (1×6 cells), referring to the GVC incomes of domestic manufacturers through participation in six GVCs.

A. *Structural Changes in the Domestic Manufacturing GVC*

We now investigate GVC income created each year by industries that participate in the GVC organized by the Korean manufacturing sector. Figure 6 presents the proportion of each industry's value-added (i.e., GVC income) in Korea's total manufacturing output. Along with the VAX ratio in section 3, the GVC income ratio within the domestic manufacturing GVC can be used to measure the extent to which the domestic manufacturing sector has been internationalized over the sample period.

Specifically, the proportions of GVC income generated by foreign industries in the GVC gradually increased from 24.5% in 1995 to 37.5% in 2011. Among the three foreign industries, the share for the agricultural sector increases the most, from 5% to 12.7%, followed by the service sector (8.6%→12.1%) and the manufacturing sector (11%→12.7%) in that order. In contrast, the shares of GVC income created by the domestic industries have all been reduced; the proportion fell the most in the agricultural sector (8.7% → 3.2%) and then service (17.3%→14%) and manufacturing sectors (49.6%→45.3%) in that order.

[8]The GVC income matrix is calculated first and is then aggregated to make the two-country, three-sector matrix. Utilities and construction are included in the service industry category.

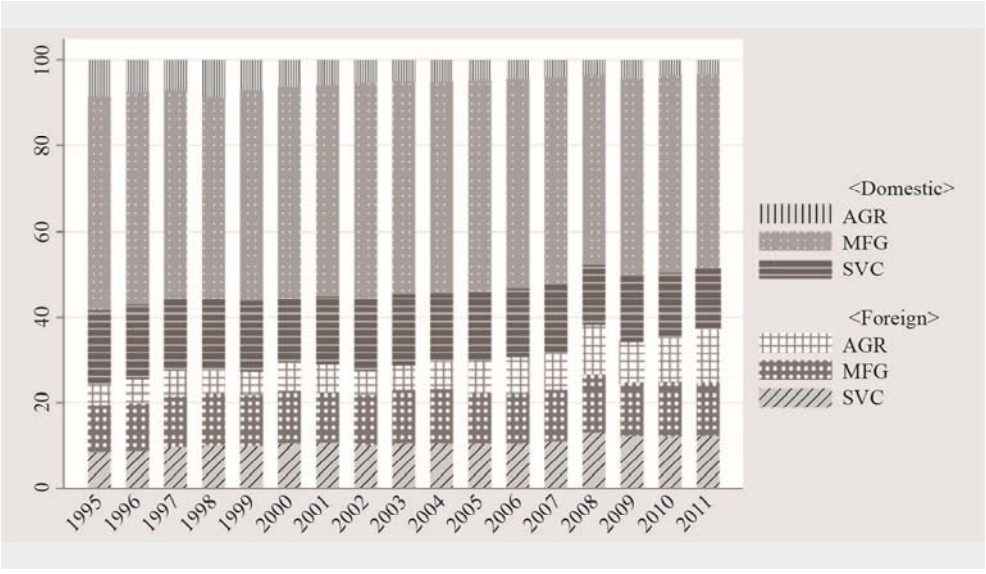

FIGURE 6. SECTORAL INCOME SHARES WITHIN THE DOMESTIC MANUFACTURING GVC

Note: Utilities and construction are included in the service industry category.

Source: World Input-Output Database (WIOD) and the author's calculations.

The trend shown in Figure 6 implies that the Korean manufacturing sector has replaced the domestic contents with foreign contents and that this is particularly true for raw materials and services. In other words, the domestic manufacturing sector has steadily intensified the internationalization of production activities by increasing raw materials and services offshoring. This rapid internationalization has indeed raised concerns regarding the hollowing out of the domestic manufacturing sector.

However, such concerns may be trivial when we take into account the total output of domestic manufacturing goods; if the total output in the manufacturing industry itself increases enough, GDP can still increase even when a significant portion is transmitted abroad through offshoring. Putting this differently, the effects that cause changes in GVC income can be divided into two parts. One is the substitution effect which arises when the domestic value-added is transmitted abroad and reduce the GDP of home country. The other is the output effect, where the variation in total output affects the level of GVC income created by the home country. If the output effect, caused by an increase in total output, is greater than the substitution effect, the GDP can still increase in the domestic manufacturing GVC.[9]

[9]For the same reason, the declining trend in the VAX ratio of Korea itself should not be a concern as long as the total export values compensate sufficiently for the decrease in the domestic value-added per unit of export value.

TABLE 5—GVC INCOME IN 1995 AND 2011

(A) 1995 ($ HUNDRED-MILLIONS, 1995 PRICE)

		KOR			ROW			GDP
		AGR	MFC	SVC	AGR	MFC	SVC	
K	AGR	139	138	31.1	0.7	10.6	9.1	329
O	MFC	11.4	793	310	9.6	217	160	1501
R	SVC	13.5	276	2726	9.6	130	161	3316
R	AGR	5.5	79	70				
O	MFC	5.6	175	139				
W	SVC	6.1	138	151				
Total		181	1600	3426				

(B) 2011 ($ HUNDRED-MILLIONS, 1995 PRICE)

		KOR			ROW			GDP
		AGR	MFC	SVC	AGR	MFC	SVC	
K	AGR	74.0	70.5	50.5	0.4	7.0	7.5	210
O	MFC	10.7	1010	384	20.6	504	507	2436
R	SVC	14.1	312	3770	13.5	243	350	4703
R	AGR	10.4	284	308				
O	MFC	6.5	282	242				
W	SVC	8.3	270	361				
Total		124	2228	5115				

(C) DIFFERENCE BETWEEN 2011 AND 1995

		KOR			ROW			GDP
		AGR	MFC	SVC	AGR	MFC	SVC	
K	AGR	-65	-68	19.4	-0.3	-3.6	-1.6	-119
O	MFC	-0.7	217	74	11	287	347	935
R	SVC	0.7	35	1044	3.9	113	190	1387
R	AGR	4.9	205	238				
O	MFC	0.9	107	103				
W	SVC	2.2	132	210				
Total		-57	628	1689				

(D) % CHANGE

		KOR			ROW			GDP
		AGR	MFC	SVC	AGR	MFC	SVC	
K	AGR	-47	-49	62	-38	-34	-18	-36
O	MFC	-6	27	24	114	132	217	62
R	SVC	5	13	38	40	87	118	42
R	AGR	89	260	342				
O	MFC	16	61	74				
W	SVC	36	96	139				
Total		-32	39	49				

Note: Data on ROW is omitted in order to concentrate on Korean industry.

Source: World Input-Output Database (WIOD) and the author's calculations.

Analyzing the changes in GVC income by isolating one effect from the other requires a more sophisticated model along with more specific data. Given the delicacy and availability of our model and data, we can at least identify which of the two effects is greater within the given period of time. Tables (a) and (b) in Table 5 display GVC income by industry for the years 1995 and 2011, and tables (c) and (d) show the difference and the growth rate in GVC income between the two years, respectively.

All participating industries in the Korean manufacturing GVC create added value of $160 billion in 1995, which increases by $62.8 billion (39%) to $222.8 billion in 2011. Among the $62.8 billion, $18.4 billion was created by the domestic industries, while the remaining $44.4 billion was generated by foreign industries. When calculated in terms of the growth rate, the real GVC income increases by 15% in domestic industries and 113% in foreign industries. This implies that the substitution effect increases from 1995 to 2011, but the output effect is even greater, making the net effect increase the real domestic GDP by 15%.[10] This result is consistent with recent studies that find a positive effect of foreign investment on domestic activities (e.g., Desai *et al*. 2009, Jang and Hyun 2012).

[10]Offshoring affects both the substitution and output effect directly, but the output effect cannot be fully explained by offshoring alone, as it is also caused by productivity growth through technical progress.

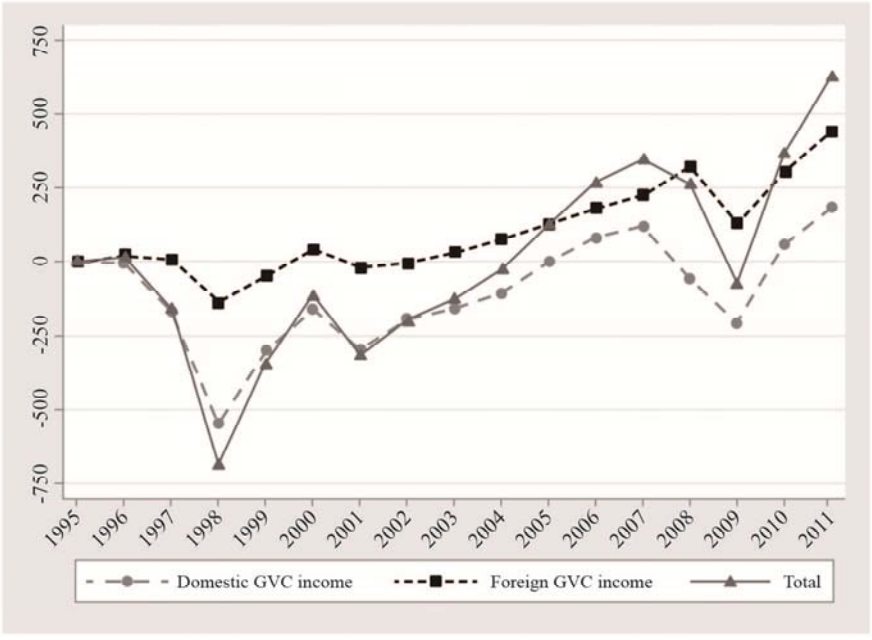

FIGURE 7. GROSS OUTPUT DIFFERENCES OF DOMESTIC MANUFACTURING COMPARED TO 1995

Note: GVC income adjusted to 1995 constant hundred-million US$.

Source: World Input-Output Database (WIOD) and the author's calculations.

However, in the domestic agricultural sector, GVC income decreases regardless of the increase in total output because the substitution effect is greater than the output effect. The GVC income of the domestic service sector does not increase as much. These phenomena imply that the size of the output effect may not always outweigh the substitution effect, as the substitution effect gradually intensifies through offshoring, while the output effect is easily influenced by aggregate shocks, such as recessions or financial crises, leading to a significant drop in GVC income. Thus, it is necessary to observe the change in GVC income by separating the two effects for all years in comparison with the base year of 1995.

Figure 7 plots the trend in the differences in the GVC income levels for each year from the level in 1995. The total output differences for each year are then divided into those of the domestic and foreign value-added. The GVC income of foreign industries rises gradually with small dips and marks steadily above the level for 1995, except for the period of the financial crisis in the 1990s. On the other hand, the GVC income of domestic industries is rather turbulent with significant drops in response to the sharp economic shocks in the late 1990s and late 2000s. The output effect over the course of the year is not large enough to offset the substitution effect, and Korea's real GDP by participating in the domestic manufacturing GVC remained lower than that of 1995 until recently.

As the location of production activities has shifted from Korea to foreign countries, the employment structure is expected to exhibit a pattern identical to that of the income structure. To confirm the validity of this statement, we put GVC

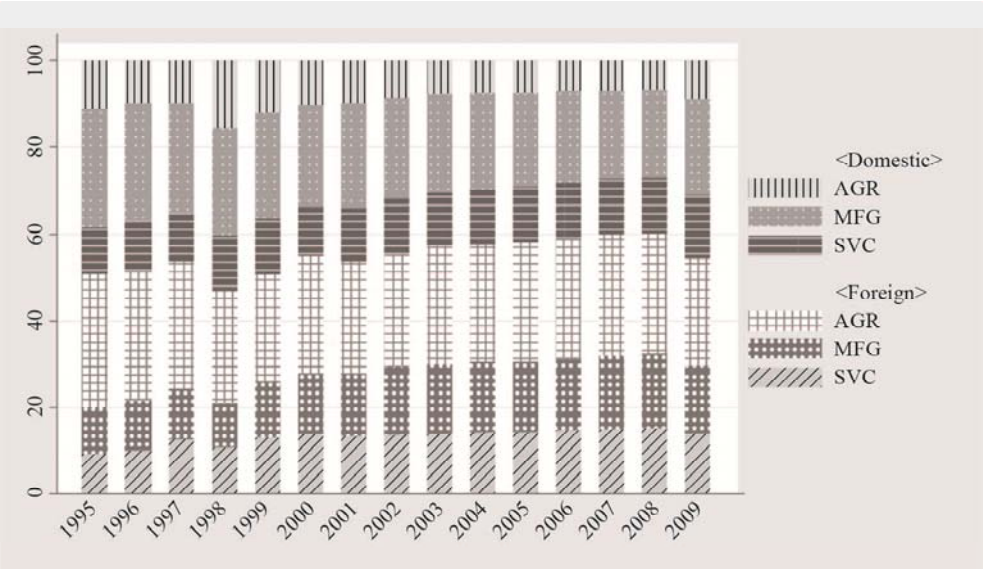

FIGURE 8. SECTORAL EMPLOYMENT SHARES IN THE DOMESTIC MANUFACTURING GVC

Note: Utilities and construction are included in the service industry category.

Source: World Input-Output Database (WIOD) and the author's calculations

employment in place of GVC income in Table 4. Subsequently, Figure 8 shows the GVC employment shares in the Korean manufacturing GVC. WIOD's SEAs provides data on national and industrial characteristics during the period from 1995 to 2009.

In Figure 8, we find the increase in the proportion of foreign GVC employment, just as in the case of GVC income. Specifically, in 1995 domestic and foreign workers numbered 4.7 million and 4.9 million, respectively, corresponding to 49% and 51% of the total working population in the domestic manufacturing GVC. However, 3.6 million domestic workers and 5.5 million foreign workers account for 40% and 60%, respectively, of the total labor force in 2008.[11] The substitution effect from the domestic to foreign industries occurs in GVC employment as well.

The structure of GVC income and employment are not identical in all respects however. One difference that stands out is that the proportion of foreign labor input is generally higher than that of foreign income. Foreign workers participating in the domestic manufacturing GVC already accounted more than 50% of the total labor force in 1995. The employment share in the foreign agricultural sector is especially high, presenting a stark contrast to the share in income in the agricultural sector. This suggests that the difference in the labor wage between the domestic and foreign industries is one of the main reasons for offshoring.

Dividing GVC income by GVC employment in each cell gives the labor

[11]We excluded 2009 data because in 2009, production and employment plummeted as the global financial crisis hit the world economy. Although 2008 was also affected by the exchange rate shock during the initial phase of the crisis, we still use 2008 data, as the GVC income shares for that year appear to be closest to those of 2011 and because its GVC employment shows a pattern similar to that for 2007.

TABLE 6—GVC EMPLOYMENT AND REAL LABOR PRODUCTIVITY IN 1995 AND 2008

(A) 1995 GVC EMPLOYMENT (TEN-THOUSANDS)

		KOR			ROW			TOT
		AGR	MFC	SVC	AGR	MFC	SVC	EMP
K	AGR	110	106	14	0.5	7.1	5.7	243
O	MFC	3.2	263	90	2.7	75	48	482
R	SVC	4.6	103	1089	4.1	51	63	1315
R	AGR	34	298	150				
O	MFC	3.2	105	76				
W	SVC	4.1	89	162				
Total		160	965	1580				

(B) 2008 GVC EMPLOYMENT (TEN-THOUSANDS)

		KOR			ROW			TOT
		AGR	MFC	SVC	AGR	MFC	SVC	EMP
K	AGR	62	61	43	0.3	4.6	4.7	175
O	MFC	1.9	184	73	2.8	80	72	414
R	SVC	4.7	116	1412	6.8	91	135	1766
R	AGR	18	258	260				
O	MFC	3.4	155	146				
W	SVC	4.0	139	193				
Total		93	913	2127				

(C) 1995 LABOR PRODUCTIVITY ($ THOUSANDS, 1995 PRICE)

		KOR			ROW			AVG
		AGR	MFC	SVC	AGR	MFC	SVC	
K	AGR	12.6	13.1	22.8	14.5	14.9	16.0	13.6
O	MFC	35.8	30.1	34.6	36.1	29.1	33.1	31.2
R	SVC	29.3	26.7	25.0	23.7	25.4	25.4	25.2
R	AGR	1.6	2.6	4.6				
O	MFC	17.4	16.7	18.2				
W	SVC	15.1	15.5	9.3				
Average		11.4	16.6	21.7				

(D) 2008 LABOR PRODUCTIVITY ($ THOUSANDS, 1995 PRICE)

		KOR			ROW			AVG
		AGR	MFC	SVC	AGR	MFC	SVC	
K	AGR	10.1	10.2	11.4	12.8	13.2	14.1	10.7
O	MFC	46.2	44.7	47.5	58.7	50.3	53.5	47.9
R	SVC	24.1	22.7	25.0	21.7	22.5	22.9	24.6
R	AGR	4.7	8.4	10.8				
O	MFC	14.5	16.3	16.1				
W	SVC	17.6	17.7	18.8				
Average		11.0	20.4	22.6				

Note: Data on ROW is omitted in order to concentrate on Korean industries.

Source: World Input-Output Database (WIOD) and the author's calculations

productivity (i.e., value-added per worker) and its trends. (a) and (b) in Table 6 show GVC employment in 1995 and 2008, respectively, and (c) and (d) in the table calculate the real labor productivity for those years. Both the share and absolute level of labor input decrease in the domestic agricultural and manufacturing sector but increase in the domestic service sector. Accordingly, the service sector labor productivity within the domestic manufacturing GVC is decreased from $26,700 in 1995 to $22,700 in 2008, showing a reduction of approximately 15%.

The main reason for the lower productivity of the service sector within the domestic manufacturing GVC is that the labor productivity in the business service industry, which is the most committed service in terms of value-added, dropped significantly from $39,300 in 1995 to $23,100 in 2008.[12] In contrast to the decline in domestic service productivity, foreign service productivity improved by 14% during the same period.

[12]See Table A3 for the service productivities engaged in the Korean manufacturing GVC at a disaggregate level.

B. *Redistribution of Production Factors within the Domestic Manufacturing GVC*

Given the finding that domestic income and employment in the Korean manufacturing GVC were replaced by foreign income and employment, respectively, through its active offshoring, we scrutinize in more detail the re-distribution of the domestic and foreign factors of production within the GVC.

Production factors that create added value can be divided in various ways depending on the classification method, but we classify them into labor and capital in this study. Capital is defined in its broadest sense and includes all production factors other than labor. On the other hand, labor is further divided into the low-skilled, middle-skilled and high-skilled types. In accordance with the standard classification method provided by the socio-economic accounts of WIOD, lower secondary or less, post-secondary to non-tertiary education, and tertiary education or above are classified as low-, middle-, and high-skilled workers, respectively.

In Table 7, the income for each of the production factors in 1995 and 2008 is calculated as a share of the total GVC income. The labor and capital income ratios in both the domestic and foreign industries add up to 100, as shown in the shaded area in the top two panels of the table. The labor income share in each industry is then divided into the shares for low-, middle-, and high-skilled labor. When examining the difference between the figures for 2008 and 1995, the income shares for low- and middle-skilled labor show a noticeable decline, by 9.7%p and 7.6%p respectively, whereas the share of high-skilled labor has increased slightly by

TABLE 7—DOMESTIC & FOREIGN SHARES OF FACTOR INCOMES WITHIN THE DOMESTIC MANUFACTURING GVC

Year	1995 (%)				
Prod. Factor	Low-skill	Mid-skill	High-skill	Labor	Capital
Domestic	13.2	26.3	18.5	**57.9**	**17.6**
Foreign	3.8	6.3	3.1	**13.2**	**11.2**
Developed	1.9	5.3	2.7	9.9	6.4
Developing	1.9	1	0.4	3.3	4.8

Year	2008 (%)				
Prod. Factor	Low-skill	Mid-skill	High-skill	Labor	Capital
Domestic	3.5	18.7	19.8	**42.0**	**19.7**
Foreign	4.2	7.8	4.8	**16.8**	**21.5**
Developed	1.3	4.9	3.6	9.8	7.1
Developing	2.9	2.8	1.3	7.0	14.4

Year	2008 - 1995 (%p)				
Prod. Factor	Low-skill	Mid-skill	High-skill	Labor	Capital
Domestic	-9.7	-7.6	1.3	-15.9	2.1
Foreign	0.4	1.5	1.7	3.6	10.2
Developed	-0.6	-0.4	0.9	-0.1	0.7
Developing	1.0	1.8	0.9	3.7	9.6

Note: Developed country consists of 20 out of 40 WIOD countries, excluding Korea. They are Australia, Austria, Belgium, Canada, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, Portugal, Sweden, Taiwan, and the United States. The rest of the WIOD countries plus ROW are classified as developing countries.

Source: World Input-Output Database (WIOD) and the author's calculations.

1.3%p. Due to the significant drop in the shares of low and middle-skilled income, the total labor income share has also been reduced by 15.9%, while the total capital income share has increased by 2.1%p. In consequence, the labor share of total factor income has decreased by 9%p, from 77% in 1995 to 68% in 2008.

The 13.8%p reduction in total in the domestic income shares has been replaced by increases in all of the foreign factor income shares. Note that, however, the increment of each share in the foreign industries is not proportional to that in the domestic industries. For example, despite the significant drops in the low- and middle-skilled labor income shares of domestic industries, the corresponding shares of foreign industries increased only slightly, by 0.4%p and 1.5%p, respectively. Meanwhile, it is interesting to note that high-skilled foreign labor income has increased even more, by 1.7%p.

The higher increase in the high-skilled labor income share is most likely due to the various destinations for production offshoring. For example, the manufacturers of leading-edge products and professional business services are likely to be offshored in advanced countries, increasing the high-skilled income share within the foreign industry. On the other hand, the low- and middle-skilled income shares may increase in developing countries, which are involved in simple assembly production processes.

Therefore, we divide the factor income shares into those of developed and developing countries. As expected, low- and middle-skilled income shares decreased in developed countries but increased in developing countries. However, the corresponding increments are only 1% and 1.8% in developing countries, and these levels do not appear to be high enough to compensate for the reduction in the domestic income shares. Rather, it is the increment in the capital income share in developing countries (9.6%p) that compensates for most of the reduction of the domestic income shares. But again, this result is not surprising, as developing countries tend to maintain a higher rate of return on their scarce capital, as explained in Timmer *et al.* (2014).

In the same manner presented in Table 7, we finally show in Table 8 the GVC employment shares by skill level between domestic and foreign industries within the domestic manufacturing GVC. The shaded areas in the top two panels of the table add up to 100, and the foreign employment shares are divided into those of developed and developing countries, as was done before. Moreover, we report the real average wages for each skill level by dividing labor income by the corresponding number of workers employed for a clearer understanding of the redistribution of the different types of labor across countries and industries within the GVC.

In the table, we note that the changes in the employment shares present a pattern similar to those of income shares. The high-skilled labor share has increased while the middle- and low-skilled labor shares have decreased within the domestic industries. The patterns of the increased high-skilled labor share and decreased low-skilled labor share are also evident in the foreign industries. Moreover, the middle- and high-skilled labor shares have increased greatly while the low-skilled labor share remained the same in developing countries.

The phenomenon by which the income and employment shares of middle- and high-skilled labor increase more than those of low-skilled labor is consistent with

TABLE 8—DOMESTIC & FOREIGN SHARES OF EMPLOYMENT AND CORRESPONDING AVERAGE REAL WAGES WITHIN THE DOMESTIC MANUFACTURING GVC

Year	1995					
	Employment (%)			Wage ($ thousands)		
Prod. Factor	Low	Mid	High	Low	Mid	High
Domestic	**13.8**	**23.5**	**11.6**	15.8	18.5	26.4
Foreign	**38.7**	**10.6**	**1.8**	-	-	-
Developed	1.2	2.4	0.8	27.8	36.7	56.9
Developing	37.5	8.2	1	0.8	2.1	6.1

Year	2008					
	Employment (%)			Wage ($ thousands)		
Prod. Factor	Low	Mid	High	Low	Mid	High
Domestic	**4.4**	**19.5**	**15.8**	23.2	27.8	36.1
Foreign	**38.5**	**17.6**	**4.2**	-	-	-
Developed	1	2.8	1.3	38.5	50.2	79.6
Developing	37.5	14.8	2.9	2.2	5.5	12.4

Year	2008 – 1995					
	Employment (%p)			Wage ($ thousands)		
Prod. Factor	Low	Mid	High	Low	Mid	High
Domestic	-9.4	-4	4.2	7.4	9.3	9.7
Foreign	-0.2	7	2.4	-	-	-
Developed	-0.2	0.4	0.5	10.7	13.5	22.7
Developing	0	6.6	1.9	1.4	3.4	6.3

Note: Developed country consists of 20 out of 40 WIOD countries, excluding Korea. They are Australia, Austria, Belgium, Canada, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, Portugal, Sweden, Taiwan, and the United States. The rest of the WIOD countries plus ROW are classified as developing countries.

Source: World Input-Output Database (WIOD) and the author's calculations.

the claim by Feenstra and Hanson (1997, 1999). These authors argue that the tasks that were once done by unskilled labor in advanced countries are now completed by middle- or high-skilled workers of developing countries, thus decreasing the demand for unskilled labor in developed countries while increasing the demand for and income of skilled labor in developing countries.

Finally, the table indicates an exacerbated degree of wage inequality between skilled and unskilled labor in all country groups, which again confirms the claim made by Feenstra and Hanson (1997, 1999).[13] Compared to foreign countries, however, the relative wage gap according to skill level is not that large in Korea. Perhaps this can be explained by the fact that the high college enrollment rate has increased the share of high-skilled labor in Korea.

C. *Change in the Pattern of Domestic Manufacturers' GVC Participation*

We now turn our attention to the trends of GVC incomes domestic manufacturers create by participating in GVCs as suppliers. As shown in Table 4,

[13]Jeon *et al*. (2013) employ Feenstra and Hansen's (1997, 1999) empirical strategy to identify the offshoring and trade effect on the wage premium in Korean industries. Their result is consistent with ours.

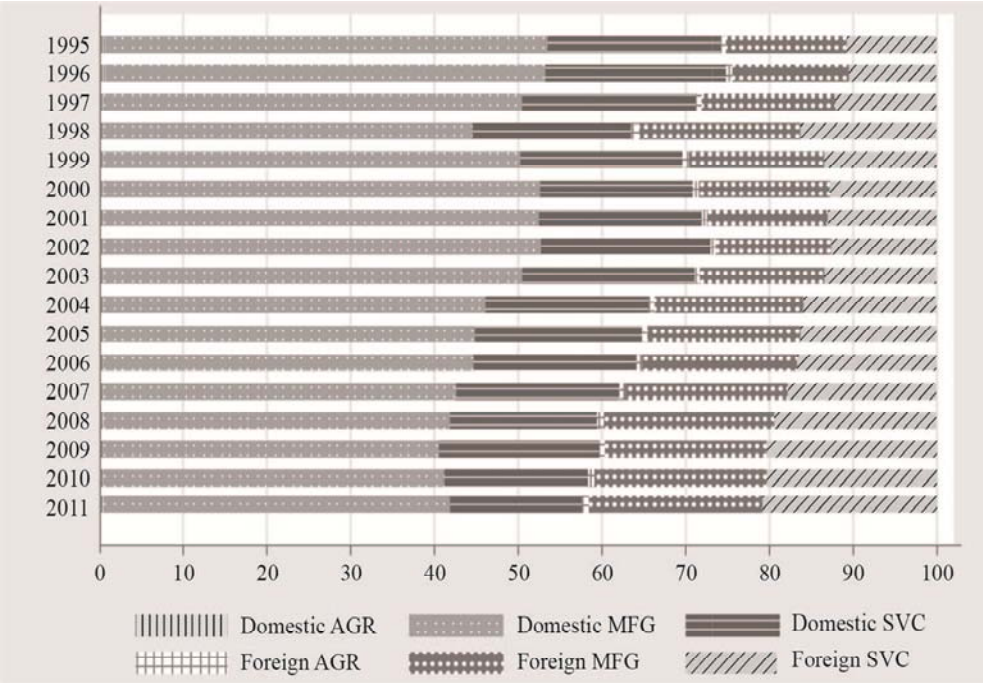

FIGURE 9. INCOME SHARES OF DOMESTIC MANUFACTURING BY PARTICIPATING IN SIX GVCS

Source: World Input-Output Database (WIOD) and the author's calculations

there are six GVCs joined by domestic manufacturers as suppliers including its own. The second row in the table refers to the GVC incomes generated through its participation. GVC income in each cell is then depicted in Figure 9 as a percentage of the total, which forms the GDP of the domestic manufacturing industry.

The GVC income share from participating in the three foreign GVCs is 25.7% for 1995, and it gradually increases to 42.3% for 2011. Specifically, 42.3% of the domestic manufacturing GDP is generated by participating in foreign GVCs. In addition, the income generated by participating in foreign GVCs has been greater than the income through its own GVC since 2009. Therefore, the production of intermediate goods to sell in the global market plays a more significant role for domestic manufacturers as compared to the production of final goods. Thus, the participation of domestic manufacturers as suppliers in foreign GVCs is as conspicuous as the participation as an organizer; the levels have been active in both cases.

We can find how much of the domestic manufacturing GVC income changes in each of the six GVCs by looking at the second rows of (a) through (d) in Table 5. For example, as shown in (d) in the table, the domestic manufacturing GVC incomes change by -6%, 27%, and 24% within domestic GVCs, whereas these levels increase by 114%, 132%, and 217% in the foreign GVCs. Therefore, more than two-thirds (69%) of the increase in the domestic manufacturing GDP between 1995 and 2011 can be attributed to the income generated by participating in foreign GVCs as suppliers.

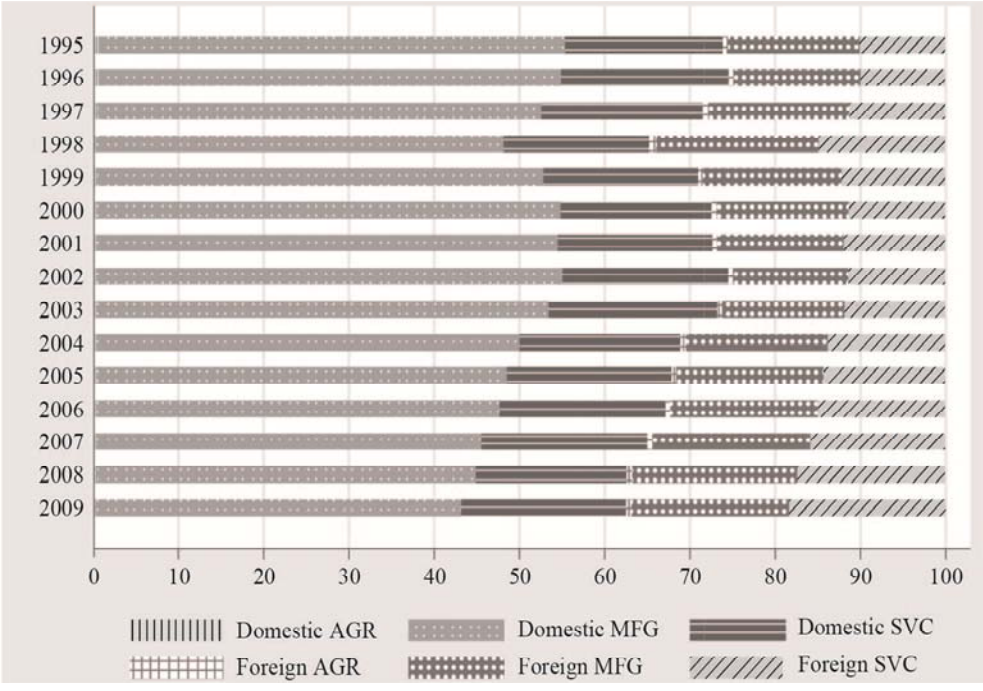

FIGURE 10. EMPLOYMENT SHARES OF DOMESTIC MANUFACTURING BY PARTICIPATING IN SIX GVCS

Source: World Input-Output Database (WIOD) and the author's calculations.

Figure 10 provides information about the domestic manufacturing GVC employment created by both home and foreign GVCs. As in the case of GVC income, the GVC employment share within the foreign GVCs increases from 26.1% in 1995 to 37.4% in 2008. The GVC income and employment shares are similar in 1995 (26%), but over time we find that the income share surpasses the employment share. In other words, the same domestic manufacturers happen to have higher productivity when participating in foreign GVCs than in the domestically organized GVCs. This is illustrated in the second rows of (c) and (d) in Table 6.

If the result above is true, it is plausible that the suppliers of intermediate goods to export abroad have higher productivity than those that satisfy the domestic demand. The reason for the higher productivity cannot be explained directly in this study, but related literature gives interesting explanations, such as the tendency of highly productive firms to enter export markets (Melitz 2003) and the learning effect of exporting firms to become highly productive (De Loecker 2013).

V. Concluding Remarks

Global value chains have been widespread in recent decades due to technological developments and greater trade openness across countries. Firms now have more options than before regarding how to produce a good; by strategically organizing their production sequences on a global scale, they can

improve their efficiency and thus the competitiveness of their products.

How have Korean industries utilized this changing environment and what are the consequences? To answer this question, we formally measure the extent to which Korea has participated in GVCs over the last two decades and evaluate how this level affects the value-added and employment structure in the Korean manufacturing industry. It was found here that Korea is one of the countries that participated in GVCs most actively between 1995 and 2011, both as the organizer of its own GVC and as a supplier of foreign GVCs. As a result, the final products of the Korean manufacturing industry contain a greater value-added from foreign labor and capital than before, which in turn reduces the ratio of value-added exports to gross exports. At the same time, however, Korean manufacturers also increased their contribution to foreign GVCs by supplying intermediate goods, thereby accounting for more than 50% of the total manufacturing GDP. Another result of Korea's active GVC participation is the reallocation of labor within the domestic manufacturing industry toward skilled workers and thereby an increase in the wage premium.

Although the findings above are mainly to inform the reader of the overall trend in the international activities of Korean industries, they still have several policy implications. The first is related to the need to strengthen the input competitiveness of domestic industries. The GVC perspective emphasizes that we should focus more on contributing to the product than on the selling price. Thus far, Korea has been good at exports, but in many exporting products, the core inputs with high value-added tend to be outsourced from foreign countries, particularly Japan. This tendency is more evident in major exporting industries and thus reduces the contribution of exports to GDP, as shown in Table 2 and Figure 4.[14] Therefore, domestic industries need to develop the ability to provide highly valued inputs in this GVC world. Note also that the need to strengthen the input competitiveness is not specifically limited to manufactured goods. Figure 6 shows that significant service inputs are embedded in manufactured goods, but the competitiveness of Korean services has been weak, as indicated in Figure 5.

The second policy implication, related to the first, is to provide more incentives to firms to locate their production facilities in Korea. In the end, the GDP is created only when production activities occur within domestic territories. The high reliance on offshoring can seriously hamper domestic economic growth when global demand shrinks, as shown in Figure 7. On the other hand, Tables 5 and 6 (as well as Figures 9 and 10) indicate that domestic industries create ever-growing amounts of value-added and employment by participating foreign GVCs as intermediate goods exporters. Hence, it is important to incentivize firms to locate and produce within Korea, regardless of whether they are domestic- or foreign-owned. Korea has been in fact unattractive to foreign firms, as the ratio of inbound FDI stock to GDP was only 13.7% in 2013, the third lowest among all OECD countries.[15]

Thirdly, industrial policies should reflect the trend of foreign final demand. As shown in Figure 3, close to one-third of Korean GDP was created by foreign final

[14]Recall that the VAX ratios of three major exporting industries are just about 0.4.

[15]The average ratio of inward FDI stock to GDP in all OECD countries is 61.1%, while the ratios of Japan and Greece are 3.5% and 11.5%, respectively.

demand in 2011, and this reliance on foreign final demand has been much larger than in 1995. As Korea has become one of the most globalized countries, its economy can easily be affected by foreign economic shocks. Thus, suitably managing such foreign shocks should be essential to the economic success of Korea. In particular, Table 3 indicates that China is now the largest single consumer of Korean value-added, which implies that structural changes in Chinese final demand can systematically affect Korea's production and exports (see Chung 2015 for more details).

APPENDIX

In this appendix, we derive the equations for GVC income, GVC employment, and value-added exports. Suppose there are N countries and S sectors in each country. Each country produces only one good (or service) within each sector. Hence, there are $N \times S$ goods in the world that can be used as either an intermediate good (m) or a final good (f). We denote $y_i(s)$ as the output of sector s in country i for a given year. Let the final demand in country j for good s produced in country i be $f_{ij}(s)$, and the intermediate demand in sector s' in country j for the good s in country i be $m_{ij}(s,s')$.

The market clearing condition for the good s in country i is then given by

$$y_i(s) = \sum_j f_{ij}(s) + \sum_j \sum_{s'} m_{ij}(s,s') = \sum_j \left[f_{ij}(s) + \sum_{s'} m_{ij}(s,s') \right]. \tag{A1}$$

The gross exports in sector s from country i to country j is, by definition, the sum of its intermediate and final good exports:

$$x_{ij}(s) = f_{ij}(s) + \sum_{s'} m_{ij}(s,s'). \tag{A2}$$

It is convenient to express above equations in vector and matrix notations. First, we define the following notations.

y_i : output of country i $(S \times 1)$

y : output of all countries $(SN \times 1)$

f_{ij} : final demand of country j for all goods from country i $(S \times 1)$

f_j : final demand of country j for all goods from all countries $(SN \times 1)$

$f = \sum_j f_j$: final demand of the world for all goods from all countries $(SN \times 1)$

$a_{ij}(s,s') \equiv m_{ij}(s,s') / y_j(s')$: unit value of good s in country i to produce one unit (value) of good s' in country j, i.e., the input coefficient

A: input coefficient matrix where $a_{ij}(s,s')$ is a typical element $(SN \times SN)$

$r_i(s) = 1 - \sum_j \sum_{s'} a_{ji}(s',s)$: value-added to output ratio in good s in country i

R: diagonal matrix where $r_i(s)$ is a typical element $(SN \times SN)$

F: diagonalized matrix of f $(SN \times SN)$

(A1) can then be rewritten in the form of the equation on the left in (A3), which can further be solved for y as in the equation on the right-hand side in (A3),

$$\text{(A3)} \qquad y = Ay + \sum_j f_j \Leftrightarrow y = (I - A)^{-1}\left[\sum_j f_j\right] = (I - A)^{-1} f$$

where $(I - A)^{-1}$ is the Leontief inverse. This matrix measures how much each sector in each country should produce to satisfy one unit of final demand in the world. Therefore, pre-multiplying the Leontief inverse by R gives the value-added in each sector created by one unit of world final demand.

GVC income is obtained when post-multiplying $R(I - A)^{-1}$ by the actual (diagonalized) final demand in the world (F), i.e.,

$$\text{(A4)} \qquad GVC\ income = R(I - A)^{-1} F.$$

GVC income can be decomposed further into the incomes by production factors, as we know the income share of each production factor. For example, if the labor income share of the total value-added in sector s in country i is $w_i(s)$, the GVC labor income is obtained as follows,

$$\text{(A5)} \qquad GVC\ labor\ income = WR(I - A)^{-1} F,$$

where W is the diagonal matrix with the $w_i(s)$ elements.

GVC employment is obtained when replacing the labor input-to-output ratio, $l_i(s)$, with R in (A4), i.e.,

$$\text{(A6)} \qquad GVC\ employment = L(I - A)^{-1} F$$

where L is the diagonal matrix with the $l_i(s)$ elements. As in GVC income, GVC employment can also be decomposed into the employment by skill level (e.g., low-,

medium-, and high-skilled workers) if we know the distribution of employment at different skill levels.

Meanwhile, value-added exports (VAX) of sector s from country i to country j is calculated as

$$VAX_{ij}(s) = r_i(s)\, y_{ij}(s), \tag{A7}$$

where $y_{ij}(s)$ is the output produced in sector s of country i due to the final demand in country j. Finally, the VAX ratio of country i is defined as the ratio of its aggregate value-added exports to the aggregate gross exports, i.e.,

$$VAX\ ratio_i = \frac{\sum_j \sum_s VAX_{ij}(s)}{\sum_j \sum_s x_{ij}(s)}. \tag{A8}$$

WIOT provides all of the necessary information, including industry-level outputs (y), final demand (f), intermediate demand (A), value-added ratio (R), and labor input (L). Table A1 and Table A2 show the industry classification and sample countries in the WIOT, respectively.

TABLE A1—INDUSTRY CLASSIFICATION IN THE WIOT AND CORRESPONDING KSIC9

Industry number	Industry name	KSIC9	Three-sector classification
1	Agriculture, Hunting, Forestry and Fishing	A	Agriculture
2	Mining and Quarrying	B	
3	Food, Beverages and Tobacco	10t12	Manufacturing
4	Textiles and Textile Products	13t14	
5	Leather, Leather and Footwear	15	
6	Wood and Products of Wood and Cork	16	
7	Pulp, Paper, Printing and Publishing	17t18, 58	
8	Coke, Refined Petroleum and Nuclear Fuel	19	
9	Chemicals and Chemical Products	20t21	
10	Rubber and Plastics	22	
11	Other Non-Metallic Mineral	23	
12	Basic Metals and Fabricated Metal	24t25	
13	Machinery, Nec	285, 29	
14	Electrical and Optical Equipment	26t27, 281t284, 289	
15	Transport Equipment	30t31	
16	Manufacturing, Nec, Recycling	32t33, 37t39	
17	Electricity, Gas and Water Supply	D	Service
18	Construction	F	
19	Sale, Maintenance and Repair of Motor Vehicles	45, 952	
20	Wholesale Trade and Commission Trade	46	
21	Retail Trade; Repair of Household Goods	47, 951, 953	
22	Hotels and Restaurants	I	
23	Inland Transport	49	
24	Water Transport	50	
25	Air Transport	51	
26	Other Supporting and Auxiliary Transport Activities	52	

TABLE A1—INDUSTRY CLASSIFICATION IN THE WIOT AND CORRESPONDING KSIC9 (*CONTINUED*)

Industry number	Industry name	KSIC9	Three-sector classification
27	Post and Telecommunications	61	Service
28	Financial Intermediation	K	
29	Real Estate Activities	68	
30	Renting of M&Eq and Other Business Activities	62t63, 69t75	
31	Public Admin and Defense; Compulsory Social Security	O	
32	Education	P	
33	Health and Social Work	Q	
34	Other Community, Social and Personal Services	50t60, R, 94, 96	
35	Private Households with Employed Persons	T	

TABLE A2—SAMPLE COUNTRIES IN THE WIOT

Country code	Country name	Country code	Country name
AUS	Australia	ITA*	Italy
AUT*	Austria	JPN	Japan
BEL*	Belgium	KOR	Korea
BGR*	Bulgaria	LTU*	Lithuania
BRA	Brazil	LUX*	Luxembourg
CAN	Canada	LVA*	Latvia
CHN	China	MEX	Mexico
CYP*	Cyprus	MLT*	Malta
CZE*	Czech Republic	NLD*	Netherlands
DEU*	Germany	POL*	Poland
DNK*	Denmark	PRT*	Portugal
ESP*	Spain	ROM*	Romania
EST*	Estonia	RUS	Russia
FIN*	Finland	SVK*	Slovakia
FRA*	France	SVN*	Slovenia
GBR*	United Kingdom	SWE*	Sweden
GRC*	Greece	TUR	Turkey
HUN*	Hungary	TWN	Taiwan
IDN	Indonesia	USA	United States
IND	India	ROW	Rest of the world
IRL*	Ireland		

Note: * indicates EU27 countries.

TABLE A3—VALUE-ADDED AND LABOR PRODUCTIVITY IN KOREAN SERVICE INDUSTRIES

Industry	2008 Value-added ($ hundred million)	1995 Labor productivity ($ thousands)	2008 Labor productivity ($ thousands)
Wholesale	32.3	13.3	15.1
Retail	23.2	13.6	14.7
Inland Transport	23.7	25.1	27.3
Finance & Insurance	39.1	41.3	54.0
Real Estate	15.1	144.4	94.6
Business Services	68.5	39.3	23.1

Note: 1995 constant prices.

Source: World Input-Output Database (WIOD) and the author's calculations.

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How Large are Local Human Capital Spillovers?: Evidence from Korea

By WOORAM PARK*

This paper examines the empirical magnitude of local human capital spillovers in Korea during the 1980s and mid-1990s. Local human capital spillovers exists if plants in regions with a higher level of human capital can produce more given their own amount of input (Moretti 2004c). In particular, this paper explores an educational reform in South Korea which exogenously induced a large amount of variation in regional human capital levels. Using annually collected plant level data, I explore the effect of changes in the regional human capital levels induced by this reform on plant productivity in Korea. My results suggest that this effect is limited. I find a positive correlation between a regional level of human capital and plant productivity. However, after further addressing endogeneity using an instrumental variable, the effect of the overall regional human capital level on productivity decreases and becomes statistically insignificant.

Key Word: Local Human Capital Spillovers, Plant Productivity, Instrumental Variable, College Education, South Korea
JEL Code: J24, I20, O40

I. Introduction

Human capital externalities have been considered as a major source of economic growth and are thus of interest to both economists and policymakers (Lucas 1988). Hence, many theories suggest possible mechanisms that can lead to human capital externalities. Local human capital spillover, which involves face-to-face interaction among individuals, is argued by many as a main source of human capital externalities. This idea goes back at least to Marshall (1890) and was more recently suggested by Arrow (1962) and Romer (1986). According to this view, geographical proximity between workers is an important condition for human capital spillover, as exchanges of ideas through personal interaction is assumed to decrease with distance. This view of the mechanism of human capital spillover

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has been used to argue for the importance of cities as engines of economic growth (Jacobs 1970). The literature proposing local human capital spillover suggests that worker productivity will be positively affected by the human capital of other workers within the geographical region through personal interactions between workers that may lead to human capital spillover. Thus, local human capital spillover implies that a plant in a region with a higher level of human capital could produce a greater given human capital level of their own workers. In other words, local human capital spillover exists if the productivity of the plant is positively affected by the human capital level in other plants located nearby (Moretti 2004c).[1]

The main purpose of this paper is to examine the empirical extent of local human capital spillover in the context of Korea during the 1980s and early 1990s. Specifically, I provide new evidence of the magnitude of local human capital spillover in Korea using plant productivity. In particular, I closely follow the methodology of Moretti (2004c), a study which uses plant-level data to provide evidence of the magnitude of local human capital spillover in the U.S. This paper adds to the literature by exploring the role of spillover through personal interactions in the context of a (then) developing country. In particular, despite the widespread belief regarding the importance of human capital externalities in the growth of South Korea—e.g., Lucas (1988, 1993)—little is known about the empirical importance of local human capital spillover as a potential channel for the externalities. My results suggest the local human capital spillover through face-to-face interactions between workers beyond plant boundaries may not have been a crucial factor in Korea's growth during the 1980s and 1990s.

In 1980, the Korean government implemented an educational reform that resulted in a large and discrete increase in the number of students entering college in 1981. As a result of this discrete increase in freshmen enrollment, there was a large increase in the supply of college graduates, which induced an increase in the proportion of the college graduates in the workforce. Exploiting this variation, I examine the extent of local human capital spillover in Korea. Furthermore, I propose an instrumental variable based on the implementation of the reform to examine further the potential for endogeneity in levels of cross-regional variance in human capital.

I implement this idea using 1982-1996 data from the Mining and Manufacturing Survey, as collected by Statistics Korea. The data provide detailed information on output, labor and capital, and other plant-specific characteristics such as ownership type, age, industry and location. In particular, by estimating a production function at the plant level, I examine whether region-specific increases in the share of college graduates had a positive effect on plant productivity after controlling for plant-specific inputs and characteristics. Specifically, investigating the extent of local human capital spillover based on plant-level data could be particularly useful in the context of Korea, where the size of the country is compact compared to countries such as the U.S. or China. That is, although Korean workers could move

[1]More recently, Niehaus (2012) argues that increased education levels will lead to knowledge spillover by increasing the ability of workers to learn skills from other workers. Alternatively, Acemoglu (1996) proposes that an increase in human capital could have a positive external effect on productivity without involving technology when there is a costly search between workers and firms. This type of human capital externality does not necessarily involve knowledge spillover.

across regions within a country with relatively little cost, it is costly to relocate an establishment. Thus, using plants of which the location is most stationary would be more suitable for exploring whether productivity is affected by regional characteristics.

Overall, I do not find supportive evidence of the presence of local human capital spillover. In other words, after controlling for the plants' own levels of human capital, the proportion of workers with a college education in a given region does not have a meaningful effect on a plant's productivity. The magnitude of the simple correlation between the regional level of human capital and plant productivity is similar to that observed using plant level data in the U.S. In particular, pooled regressions suggest that a one percentage point increase in the proportion of college graduates in a region is associated with a 0.7 percentage increase in productivity. However, after instrumenting for the human capital level, the effect is reduced and becomes statistically insignificant. The results from the instrumental variable analysis show that there is positive bias in the correlation between the level of human capital and productivity. Overall, the findings of the paper are in line with recent work by Huber (2012) which questions the presence of human capital spillover beyond establishment boundaries. In particular, by surveying workers in a R&D complex in England, he finds that they have limited interactions with workers outside their establishment. This may also be true in South Korea; specifically, given the long working hours in Korea during the 1980s and early 1990s, workers would have had limited time to interact with workers outside of their plants.

As stated earlier in this section, several papers examine the empirical extent of local human capital spillover. Other work documents the positive relationship between productivity and average years of schooling using cross-country data (de la Fuente and Domenech 2001). However, cross-country evidence is unlikely to reveal the magnitude of human capital externalities given that the average levels of human capital are likely correlated with characteristics that can affect productivity (Hall and Jones 1999). To overcome this shortcoming, some papers exploit arguably an exogenous variation using city- or state-level data. Overall, empirical evidence in the existing literature is mixed. For instance, Rauch (1993) and Moretti (2004a) find positive and sizable local human capital spillover on productivity, whereas Acemoglu and Angrist (2000) and Rudd (2000) find little evidence that these spillovers are significant in practice. Most papers document human capital externalities by comparing the wages of workers across regions with different levels of human capital.[2] Acemoglu and Angrist (2000) exploit state variations in compulsory schooling laws to analyze the effect of the average human capital in a state on workers' productivity; they find little evidence of externalities from of K-12 education. Moretti (2004a), on the other hand, uses the proportion of college graduates as a measure of the average human capital in a region and finds significant increases in wages associated with an increase in the share of college graduates. Iranzo and Peri (2009) reconcile the result from Acemoglu and Angrist (2000) and Moretti (2004a). In particular, these authors argue that the magnitude of

[2]Lange and Topel (2006) and Moretti (2004b) provide a good summary of the literature which uses wage data to document the social returns of education.

externalities from college education could be greater than those from secondary education. Ciccone and Peri (2006) use an alternative method to address the possibility that the use of the Mincerian equation in earlier studies could bias results toward finding a human capital externality. They find no evidence of externalities from average schooling at the city or state level in the U.S.

Moretti (2004c) examines the effect of the share of college graduates on productivity using plant-level data. His idea is that, if local human capital spillover exists, workers in a region with a higher level of human capital will be more productive and thus the plants hiring those workers would be more productive. Specifically, combining the manufacturing censuses of 1982 and 1992 with the population censuses of 1980 and 1990, he finds that the plants located in cities with high levels of human capital produce greater amounts of output with the same amount of input than otherwise similar plants located in cities with low levels of human capital. In particular, the result shows that a one percent point increase in the fraction of college graduate workers in a given region leads to a 0.5 - 0.7 percent increase in productivity.

The rest of this paper is organized into the following sections. Section II introduces the institutional background and Section III describes the data. Section IV presents the identification strategy. Section V presents results and a series of robustness checks. The last section discusses the conclusion.

II. Institutional Background

Korea offers a unique institutional setting for this type of study in that the central govern- ment controls the supply of college graduates by setting the freshmen quota, or entrance quota, for both private and public colleges.[3] The freshmen quota was strictly enforced during the 1970s and 1980s, as colleges faced severe penalties for admitting freshmen beyond the assigned quota, such as a loss of government funding and a decrease in their quotas for the following years.[4] Moreover, the government controlled the number of colleges by granting permission for the establishment of new institutions. The number of colleges remained essentially stable across regions during the period of interest.[5] In short, this setting was quite different from those in countries such as the U.S., in which college enrollment is not set in a centralized manner. Owing to the way in which college enrollment was determined in Korea, the supply of college education was less likely to be responsive to time-varying region-specific characteristics.

[3]The government determined not only the freshmen quota but also the admission guidelines for both private and public colleges.

[4]The government allowed only a small number of disadvantaged students to be accepted over the fresh- men quota. Further, the government provided an incentive for colleges to keep the actual enrollment lower than the freshmen quota. For instance, the government increased the subsidy for colleges if the actual enrollment for a given college was lower than the freshmen quota set by the government.

[5]The government eventually relaxed (in 1996) the regulations for establishing new colleges.

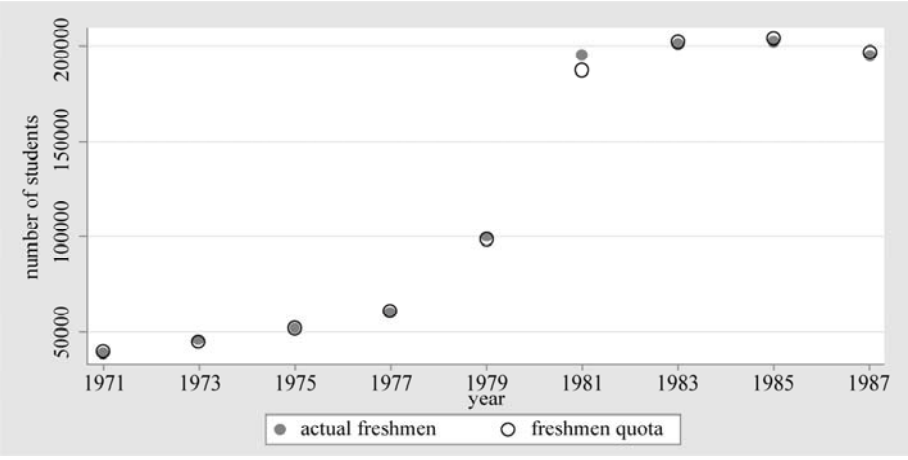

FIGURE 1. TREND OF THE FRESHMEN QUOTA AND ACTUAL FRESHMEN ENROLLMENT

Note: The solid blue circles in the figure describe the trend in the number of actual number of freshmen biannually during the period between 1971 and 1987. The hollow red dots represent the planned number of freshmen, i.e., the freshmen quota, during the corresponding period.

Until 1980, the government only allowed a gradual increase in the freshmen quota despite a large increase in the demand for college education in the 1970s. As a result, the number of 'repeat applicants', referring to who were forced to apply to colleges for more than one year to receive higher education, accumulated as the quota was not sufficient to accommodate all of the students who wanted to enter college.

However, in 1981, the freshmen quota discretely jumped due to an unexpected education reform announced on July 30, 1980 (Choi 1996).[6] The main purposes of the reform were to: i) increase the probability that students from disadvantaged backgrounds would receive a college education, and ii) reduce the number of 'repeat applicants'. The major component of the reform was a discrete increase in the freshmen quota to accommodate more students.[7] Figure 1 describes the mandated increase in the freshmen quota and the corresponding increase in freshmen enrollment in 1981 as stipulated in the reform. It is clear that this large increase was a one-time event, as the freshmen quota was stable during the 1980s after the initial increase in 1981.

Importantly, the central government forced each and every college to increase the freshmen quota in essentially the same manner. That is, the magnitude of the increase was not endogenously adapted to each college to accommodate the region-specific demand for higher education. In particular, the implementation of the increase in the freshmen quota was more or less mechanical—in general, the

[6]President Park Chung-hee, who was in office for more than 15 years, was assassinated by his body guard on October 26, 1979. After the assassination, the military junta lead by General Chun Doo-hwan gained control after a series of coups. Many people hoped a democratic government would be established after the assassination, and, as a result, this military junta was not popular. To gain popularity, the junta announced the education reform on July 30, 1980.

[7]Other components included prohibiting private tutoring and abolishing college-specific entrance exams.

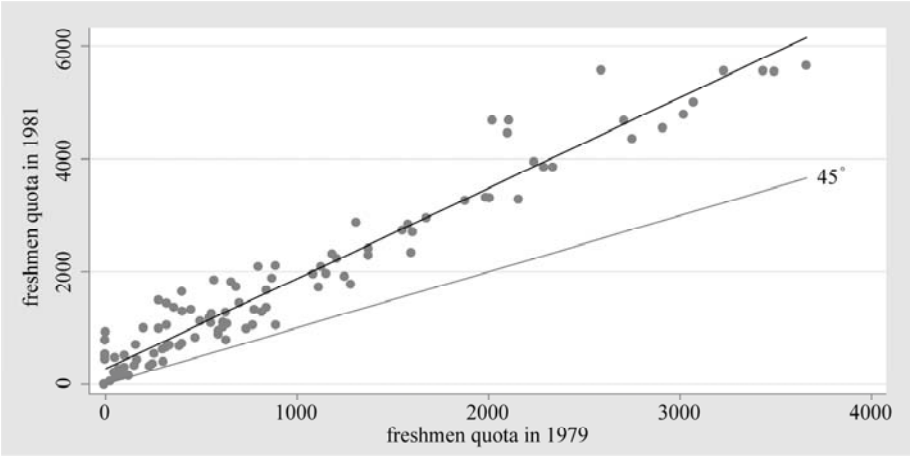

FIGURE 2. CORRELATION BETWEEN THE FRESHMEN QUOTAS IN 1979 AND 1981 BY COLLEGES

Note: The solid blue circles in the figure describe the correlation between the freshmen quota in 1979 and that in 1981 at the college level. The solid green line is the linear fit between the freshmen quota in 1979 and that in 1981. The red line is a 45-degree line included as a reference.

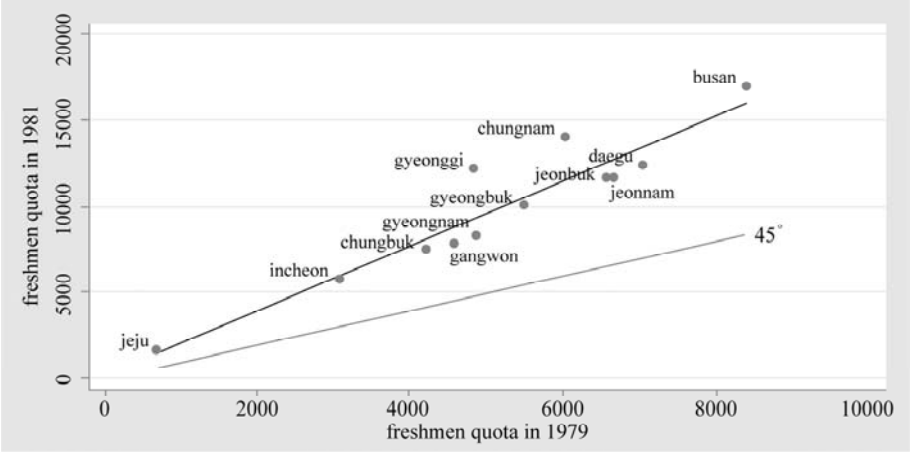

FIGURE 3. CORRELATION BETWEEN THE FRESHMEN QUOTAS IN 1979 AND 1981 BY REGION

Note: The solid blue circles in the figure describe the correlation between the freshmen quota in 1979 and that in 1981 at the college level. The solid green line is the linear fit between the freshmen quota in 1979 and that in 1981. The red line is a 45-degree line included as a reference.

government set the freshmen quota in 1981 for each college in proportion to the freshmen quota of previous years. Thus, colleges which happened to have a large freshmen quota in 1979 experienced larger absolute increases by 1981. Figure 2 plots the freshmen quota for each college in 1979 and 1981 along with a 45-degree line. This figure shows that the relationship between the freshmen quotas in 1981 and in 1979 is linear, suggesting that the freshmen quota in 1979 primarily determined the increase. The figure also shows that the absolute differences in the enrollment increase, the gap between the 45-degree line and the freshmen quota in

1981, increase as the initial freshmen quota increases.

Because the reform was consistently applied to each college, the relationships between the freshmen quota in 1979 and that in 1981 in each region are similar. Figure 3 describes the correlation between the freshmen quotas in 1979 and in 1981 in each region along with a 45-degree line. By comparing the freshmen quota in 1981 with the 45-degree line, it becomes clear that regions which happened to have higher freshmen enrollment in 1979 experienced larger absolute increases by 1981. Thus, the reform exogenously increased the difference in the supply of college graduates in each region after the mid-1980s. Furthermore, this figure confirms that the freshmen quota in 1981 in each region was indeed mostly determined by the proportional increase in the freshmen quota in 1979—the relationship between the quotas in 1979 and in 1981 is linear. The figure thus provides evidence which refutes the claim that the increase in the freshmen quota in 1981 was endogenously determined by the government.

As a result of the education reform, there was a large increase in the supply of college graduates, which induced a rapid increase in the proportion of college graduates among the workforce. More importantly, there was a large degree of arguably exogenous variation in terms of the increase in the proportion of college graduates across the regions after the mid-1980s. I use this regional variation in the impact of the reform to identify the magnitude of local human capital spillovers.

III. Data

To examine local human capital spillover using plant productivity, I use the Mining and Manufacturing Survey provided by Statistics Korea. Statistics Korea has been collecting these data since 1968, but the micro-data have only been available since 1982. Moreover, because the manufacturing sector of Korea was heavily affected by the Asian financial crisis in 1997, I only use data prior to 1997. These data were collected annually from mining and manufacturing plants with five or more workers. The survey contains detailed information about individual plants, such as their industry classification, output, production costs, locations, and tangible assets including capital.

The data also contain information on the total number of employees and the number of white-collar (non-production) employees. However, like most plant-level data, there is no information on the educational attainment levels of the workers. Thus, I proxy the change in the proportion of college graduates using the change in the proportion of white-collar workers.

To explore the validity of this proxy, I use the Basic Wage Structure Survey. These data have been collected by the Ministry of Employment and Labor of Korea and are designed to represents the wages of workers in establishments with more than ten employees. The survey collects data from individual workers from a sample of establishments representing each sector. The data contain information on wages, education, occupation and industry.[8] Using these data, I show that the trend

[8]Unfortunately, the data do not have location identifier for the establishment, thus I cannot use these data for the main analysis.

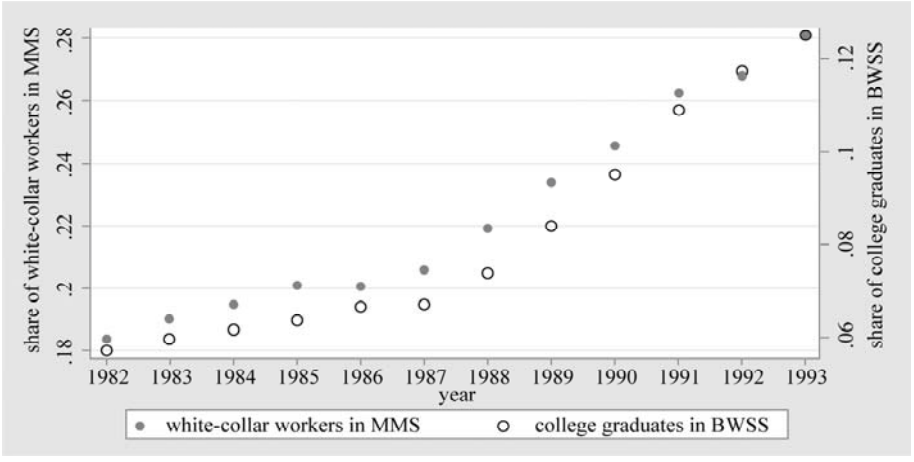

FIGURE 4. PROPORTION OF COLLEGE GRADUATE AND WHITE-COLLAR WORKERS AMONG ALL WORKERS BY YEAR

Note: The solid blue circles in the figure describe the trend in the proportion of the white-collar workers among all workers in the manufacturing sector in the Mining and Manufacturing Survey. The hollow red dots in the graph represent the share of college graduates in the manufacturing sector in the Basic Wage Structure Survey.

of the proportion of workers with college degrees coincides with the trend of proportion of white-collar workers. Figure 4 displays the share of college graduates and white-collar workers among all workers in the manufacturing sector using the Basic Wage Structure Survey and Mining and Manufacturing Survey. The time trend for white-collar workers tracks the trend of college graduates closely; both trends show a slight increase until the mid-1980s and then start to rise steeply after 1987. Thus, hereafter I use the changes in the proportion of white-collar workers as a proxy for the proportion of college graduates without further distinction.

In my main analysis, I focus on the manufacturing sector in order to ensure a consistent definition of value-added and thus productivity. Additionally, I omit years when the Mining and Manufacturing Survey was conducted as part of the Industrial Census, in this case 1983, 1988 and 1993, as variable definitions and the samples in those years are not consistent with those in other years.

Table 1 provides summary statistics. The first two columns contain the mean and the standard deviation during the period prior to the impact of the reform and columns (3) and (4) describe the corresponding mean and standard deviation of the variables after the impact of the reform. All monetary values are in 1990 Korean Won. One can verify that both the value of the output and the value-added components of individual plants increased rapidly during this period. The average output increased by nearly 50 percent between the two periods, from a base of 2.5 billion won. The average value-added amount of each plant also increased greatly, i.e., by approximately 100 percent.[9] Moreover, the average capital stock increased rapidly during the period of interest. The average capital stock of each plant was approximately 723 million won during the years 1982-1986, whereas it was about

[9]The value-added amount for each plant is defined as the value of its output less the cost of production, which includes the costs of materials and electricity.

TABLE 1—SUMMARY STATISTICS

	1982-1986		1987-1996	
	Mean (1)	Std. Dev. (2)	Mean (3)	Std. Dev. (4)
Total output (*1,000,000)	2519.0	30465.4	3844.2	52455.7
Value added (*1,000,000)	874.8	9139.7	1596.8	23646.4
Share of white-collar workers in region	0.198	0.038	0.270	0.049
Share of white-collar workers in plant	0.206	0.139	0.251	0.152
employees <25	0.216	0.131	0.250	0.143
employees >25 and <50	0.198	0.144	0.250	0.164
employees>50	0.200	0.148	0.267	0.170
Number of white-collar	14.4	88.9	12.6	94.0
Number of blue-collar	59.3	292.6	35.8	208.7
Capital (*1,000,000)	723.1	11989.0	1423.2	25697.5
Average payment (*1,000,000)	2.685	1.159	7.162	3.593
Area of building (m^2)	2084.8	17170.5	2275.2	25142.2
Age of plants	8.005	7.152	8.155	8.246
Number of jobs	121573		447807	

Note: Monetary values are in 1990 Korean Won. 1 US dollar is approximately 1,000 Won.

1.4 billion won during the years 1987-1996.

More importantly, the average proportion of white-collar workers increased by a considerable amount. In particular, the average proportion of white-collar workers within a plant increased by nearly 25 percent, or about five percentage points, after the reform went into effect. Moreover, the increase in the proportion white-collar workers did not differ significantly across differently sized plants. The proportion of white-collar workers was approximately 20 percent prior to the impact of the reform for all plant sizes, and about 25 percent after 1987, regardless of the plant size. Consistent with the increase in the proportion of white-collar workers in individual plants, the average proportion of white-collar workers in a given region also increased by a similar amount after the mid-1980s. The average payment to workers increased during this period as the total payment to workers increased by a substantial amount despite the decrease in the number of employees. The average age of an individual plant and the building area used by each plant were both stable during the years 1982-1996. Overall, the summary statistics show that many plant-level characteristics—with a few exceptions—significantly changed with the policy.

IV. Research Design and Empirical Specifications

In this section, I provide detailed information on how I use this annually collected data to examine human capital spillovers beyond plant boundaries.

The existence of local human capital spillovers implies that plants located in regions with higher levels of human capital will be more productive. Thus, one can assess the magnitude of such spillovers by examining the relationship between the level of human capital and plant productivity in each region. However, empirically estimating externalities is challenging because the change in the level of human capital is endogenous in most cases. That is, unobserved factors affecting regional plant productivity can also have a positive effect on the overall level of human

capital. For instance, the establishment of a "million dollar plant" can have a positive effect on the productivity of existing plants and can also attract workers with higher human capital (Greenstone, Hornbeck, & Moretti, 2010). In this case, a positive relationship between the level of human capital in a given region and its average plant productivity could exist even in the absence of human capital externalities. In other words, a positive correlation between the level of human capital and average plant productivity does not necessarily imply the existence of human capital externalities.

In the remainder of this section, I describe the endogeneity issue in detail using an empirical strategy adopted from Moretti (2004c). I also explain how the empirical setting in this paper helps mitigate certain associated concerns. First, I assume a Cobb-Douglas production function;

$$Y_{ijrt} = A_{ijrt} B_{ijrt}^{\alpha_b} W_{ijrt}^{\alpha_w} K_{ijrt}^{\beta} \tag{1}$$

where Y_{ijrt} is output of the plant *i*, in industry *j*, in region *r*, at year *t*. B_{ijrt}, W_{ijrt} and K_{ijrt} denote the inputs: blue-collar workers, white collar-workers, and capital, respectively. Total factor productivity is represented by A_{ijrt}. If plant productivity depends on the regional level of human capital, then $\ln A_{ijrt}$ can be expressed as follows,

$$\ln A_{ijrt} = \gamma \bar{H}_{rt} + \boldsymbol{X}'_{ijrt}\Phi + d_j + d_r + d_t + \epsilon_{rt} + \epsilon_{ijrt} \tag{2}$$

where $\overline{H}_{rt}$ is the measure of the level of human capital in a given region. In particular, similar to Moretti (2004c), $\overline{H}_{rt}$ is the proportion of college graduates in a given region *r* at time *t*. The coefficient of $\overline{H}_{rt}$, γ, represents the effect of regional human capital on productivity. Thus, the size of the local human capital spillover will be summarized to the extent to which the total factor productivity depends on the size and/or significance of γ. d_j, d_r and d_t are industry-fixed effects, region-fixed effects, and year-fixed effects, respectively. In addition to fixed effects, I control for the basic characteristics of plant i, $\boldsymbol{X}_{ijrt}$, in this case the age of the plant, the type of ownership and the area of the plant's buildings, which can affect the productivity of the plant.

After taking logs of the production function (1) and substituting for $\ln A_{ijrt}$, (1) can be rewritten as

$$y_{ijrt} = \gamma \overline{H}_{rt} + \alpha_b b_{ijrt} + \alpha_w w_{ijrt} + \beta k_{ijrt} + \boldsymbol{X}'_{ijrt}\Phi + d_j + d_r + d_t + \epsilon_{rt} + \epsilon_{ijrt} \tag{3}$$

where y_{ijrt} is the log of the value-added amount for the plant. b_{ijrt}, w_{ijrt} and k_{ijrt} are the log of the labor input of white-collar and blue-collar workers and the log capital stock, respectively. One advantage of using repeated cross-sectional data

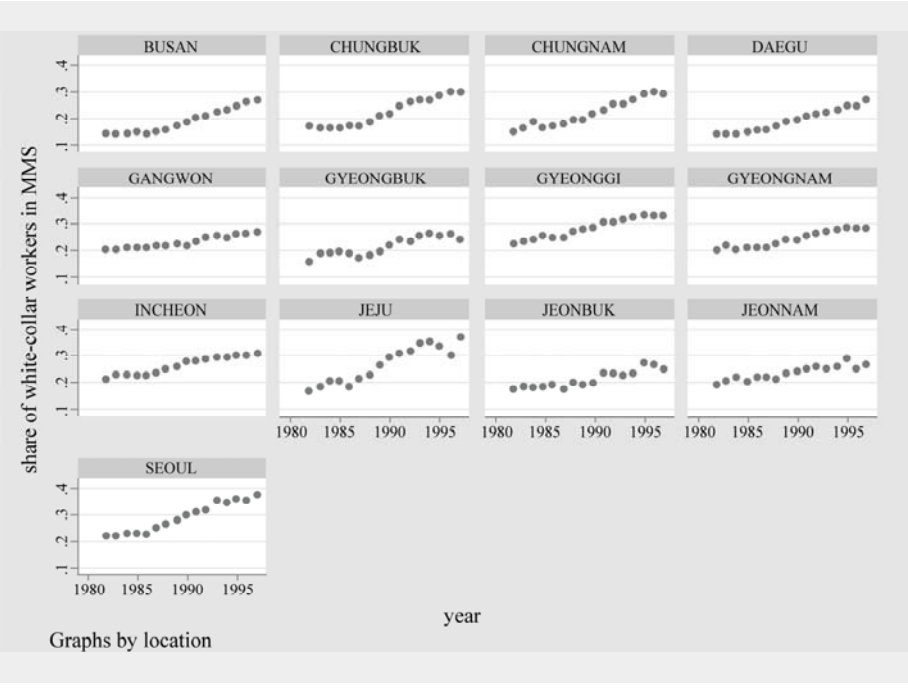

FIGURE 5: TREND IN THE PROPORTION OF WHITE-COLLAR WORKERS AMONG ALL WORKERS ACROSS REGIONS

Note: The solid blue circles in the figure describe the trend in the proportion of the white-collar workers among all workers in the manufacturing sector in the Mining and Manufacturing Survey.

is that doing so allows control over year- and region-fixed effects.[10]

The main source of endogeneity arises if time-varying region-specific shocks, ϵ_{rt}, are positively correlated with the change in the share of college graduates, $\overline{H}_{rt}$. Thus, to address this concern further, I instrument the change in the proportion of college graduates by exploiting the exogenous timing and the size of the positive supply shock in college graduates as induced by the reform. Specifically, during the period analyzed in this paper, the share of college workers in the manufacturing sector increased by a large amount. Figure 5 describes the time trend in the share of college workers proxied by white-collar workers in each region. One can observe an upward trend in most regions after the mid-1980s as well as a certain amount of variation in the increase across the regions. My approach is to use the change in the level of human capital that may be linked to the exogenous educational reform. In particular, I instrument the change in the level of human capital using the freshmen quota prior to the reform, interacted with a dummy variable indicating the periods after the impact of the reform.

To be a valid instrument, the instrument should satisfy two conditions. First, it should be correlated with the regional change in the proportion of college graduates among the workforce (the relevance condition). However, it should not be

[10]The survey does contain the plant ID. Unfortunately, the ID is not assigned consistently across years; thus, one cannot control for plant-fixed effects.

correlated with the unobserved time-varying region-specific shock, which is a source of endogeneity (the exogeneity condition).

My instrument is likely to satisfy the relevance condition if regions with a large initial size of the freshmen quota experience a larger increase in the proportion of college graduates among the workforce *after* the impact of the reform. This is perhaps due to the mechanical implementation of the policy, which is described in Section II. For instance, if a certain proportion of college graduates obtain jobs where their alma mater is located, a region with a larger initial freshmen quota would experience a larger increase in the share of college graduates among the workforce. The validity of this condition will be tested later by examining the first stage of the 2SLS estimation.

Moreover, the instrument is unlikely to be correlated with a time-varying region-specific shock due to the construction of the instrument. In particular, because the initial freshmen quota was determined prior to the implementation of the reform, it is unlikely that the initial freshmen quota will be correlated with a region-specific shock after the reform. Moreover, the timing of the implementation of the reform did not differ across regions as it was applied to each and every region in 1981. Thus, the interaction term between the two is very unlikely to be related to a time-varying region specific shock.

Using this instrument, which arguably satisfies the two conditions, I use 2SLS to examine the causal effect of, and thus to examine the extent of, the local human capital spillover. Formally, the first stage is as follows:

$$(4)\quad \overline{H}_{rt} = \pi \mathrm{POST}_t * \mathrm{PropFresh79}_{rt} + \theta_b b_{ijrt} + \theta_w w_{ijrt} + \kappa k_{ijrt} + \boldsymbol{X}'_{ijrt} \prod + d_j + d_r + d_t + \epsilon_{rt}$$

Here, $\overline{H}_{rt}$ denotes the share of college graduates among all workers, as defined earlier in this section. POST_t is a dummy variable that takes a value of one after 1986, when the share of college graduates increased due to the education reform. The relative size of the freshmen quota in 1979 in reference to total employment, $\mathrm{PropFresh79}_{rt}$, is defined as the freshmen quota in 1979 over emp_{rt}, the total number of employees in the region, *r*, at time *t*. In other words, I instrument the share of college graduates based on the assertion that the initial freshmen quota would have a stronger association with the increase in the number of highly skilled workers after the impact of the policy. This "relevance condition" could be tested by examining the statistical significance of π and the first stage, F-stat.

The second stage of the IV regression uses the predicted value of the proportion of college graduates from the first stage, $\widehat{\overline{H}}_{rt}$, and estimates with the following equation.

$$(5)\qquad y_{ijrt} = \gamma \widehat{\overline{H}}_{rt} + \alpha_b b_{ijrt} + \alpha_w w_{ijrt} + \beta k_{ijrt} + \boldsymbol{X}'_{ijrt} \Phi + d_j + d_r + d_t + \varepsilon_{rt} + \varepsilon_{ijrt}$$

Again, the coefficient of interest is γ. If the instrumental variable is valid, this second stage will address the potential positive bias associated with simple OLS

estimates further, and the estimated coefficient of $\widehat{\widehat{H}}_{rt}$ will reveal the regional human capital spillover.

V. Results

In this section, I provide the estimation results. I begin by documenting the correlation between the proportion of college graduates among workers in a given region and plant productivity. Table 2 provides the regression results for the various specifications that show a correlation. All specifications control for capital stock, labor input by type of worker, the area of the plant building and year-fixed effects. I also control for the log of capital stock per worker in each region, which helps to control for time-varying region-specific productivity shocks. Labor inputs are measured according to the number of employees, and the capital stock is measured as the monetary value of the assets excluding the value of the land. Columns (2) and (4) control for additional characteristics of the plants, such as the age, type of ownership, and industry at the two-digit level. In addition, columns (3)-(4) control for the region-fixed effects. The results in columns (1)-(2) exhibit a positive correlation between the level of human capital and plant productivity; this coincides with cross-sectional results in the U.S. as documented by Rauch (1993) and Moretti (2004c). The coefficient is consistently sizable and statistically significant across specifications. In particular, a percentage point increase in the proportion of white-collar workers in a given region—which is used as a proxy for the share of college graduates—is associated with a 0.75 percent increase in plant productivity.

TABLE 2—CORRELATION BETWEEN REGIONAL HUMAN CAPITAL LEVELS AND PLANT PRODUCTIVITY – OLS ESTIMATES

	(1)	(2)	(3)	(4)
share of white-collar workers in region	.7244***	.7498***	.4566**	.441**
	(.099)	(.0817)	(.2216)	(.2103)
ln (white-collar workers)	.4121***	.3686***	.4086***	.3661***
	(.0038)	(.0046)	(.0039)	(.0046)
ln (blue-collar workers)	.4678***	.4957***	.4658***	.4935***
	(.0033)	(.0042)	(.0031)	(.0041)
ln (capital stock)	.1736***	.1585***	.174***	.1587***
	(.0046)	(.0043)	(.0046)	(.0043)
ln (area of building)	.0409***	.0325***	.0452***	.0347***
	(.0034)	(.0031)	(.0031)	(.003)
plant age		.0069***		.007***
		(.0011)		(.0011)
Additional Controls		y		y
Regional Fixed Effects			y	y
adj. R-sq	0.809	0.815	0.809	0.816
N	569380	569380	569380	569380

Note: All specifications include the log number of white-collar and blue-collar workers, the log of capital stock and year-fixed effects. Specifications (2) and (4) additionally control for individual plant-specific characteristics such as the industry and the age of the plant. Standard errors in parentheses are clustered at the region-year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 3—EFFECT OF THE REGIONAL HUMAN CAPITAL LEVEL ON PRODUCTIVITY – IV ANALYSIS

	First stage		IV		Reduced form	
	(1)	(2)	(3)	(4)	(5)	(6)
after 1987* freshmen quota 79	.2645***	.2634***			.0622	.023
	(.0401)	(.0399)			(.1167)	(.1119)
share of white-collar workers in region			.235	.0872		
			(.426)	(.4189)		
ln (white-collar workers)	1.6e-04***	2.0e-04***	.4087***	.3662***	.4087***	.3663***
	(4.3e-05)	(4.6e-05)	(.0038)	(.0046)	(.0039)	(.0046)
ln (blue-collar workers)	-3.5e-04***	-3.2e-04***	.4658***	.4933***	.4657***	.4933***
	(7.5e-05)	(7.4e-05)	(.0031)	(.0041)	(.0031)	(.0041)
ln (capital stock)	-5.2e-05	-4.2e-05	.1740***	.1586***	.174***	.1586***
	(3.9e-05)	(4.5e-05)	(.0046)	(.0043)	(.0046)	(.0043)
ln (area of building)	4.6e-05**	-2.5e-05	.0452***	.0347***	.0452***	.0347***
	(2.0e-05)	(2.3e-05)	(.003)	(.003)	(.0031)	(.003)
plant age		1.8e-05*		.007***		.007***
		(1.0e-05)		(.0011)		(.0011)
Additional Controls		y		y		y
First Stage Fstat	43.47	43.47				
adj. R-sq	0.978	0.978	0.809	0.816	0.809	0.816
N	569380	569380	569380	569380	569380	569380

Note: All specifications include the log number of white-collar and blue-collar workers, the log of capital stock and year-fixed effects. Specifications (2), (4) and (6) additionally control for individual plant-specific characteristics such as the industry and the age of the plant. Standard errors in parentheses are clustered at the region-year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Columns (3) - (4) show that after controlling for the region-specific fixed effects, the magnitude of the main coefficient decreases, as expected. In particular, the sizes of the coefficients vary from 0.3 to 0.4, which is approximately half of the magnitude of the simple correlation between the level of human capital and productivity. However, the point estimates of the main coefficient in columns (3) and (4) are still somewhat sizable and statistically different from zero. Overall, the results from Table 2 show that a positive correlation between plant productivity and level of human capital exists in Korea. In the remainder of this section, I show that the magnitude of the coefficient decreases as I address the endogeneity further by exploring the implementation of the reform.

Table 3 conveys the results of the IV regression and the corresponding reduced-form result. Columns (1) and (2) report the first stage, and columns (3) and (4) report the second stage. Even-numbered columns additionally control for the individual characteristics of each plant. The first stage of both specifications is strong as the coefficient of the interaction term is statistically significant at the 1% level. Moreover, the F-statistics of the first-stage regression are sufficiently larger than 10. This implies that the instrumental variables are very likely to satisfy the relevance condition. The results from the second stage provide further evidence refuting the existence of human capital spillover, as the magnitude of the main coefficient is smaller than that shown in Table 2. The magnitude of the coefficient from the preferred specification is close to zero, 0.08, and is statistically indistinguishable from zero. In addition to the 2SLS result, columns (5) and (6) report the reduced-form results. Consistent with the 2SLS results, the coefficient of $\mathrm{POST}_t * \mathrm{PropFresh79}_{rt}$ is close to zero and statistically insignificant. Instrumenting the proportion of college graduates further addresses the endogeneity issue while

TABLE 4—ROBUSTNESS CHECKS OF THE IV RESULTS

	First stage		IV		Reduced form	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Omitting Intermediate Years						
after 1987* freshmen quota 79	.289***	.2872***			.0774	.0552
	(.0448)	(.0446)			(.1461)	(.1265)
share of white-collar workers in region			.2677	.1921		
			(.4847)	(.4279)		
First Stage Fstat	41.71	41.66				
adj. R-sq	0.979	0.980	0.817	0.823	0.817	0.823
N	280979	280979	280021	280021	280021	280021
Panel B: TFP Specification						
after 1987*freshmen quota79	.2645***	.2635***			.155	.0156
	(.0402)	(.04)			(.1345)	(.132)
share of white-collar workers in region			.5859	.0592		
			(.4798)	(.4962)		
First Stage Fstat	43.37	43.45				
adj. R-sq	0.978	0.978	0.257	0.276	0.257	0.276
N	569380	569380	569380	569380	569380	569380
Panel C: Translog Production Function						
after 1987* freshmen quota 79	.263***	.262***			.0794	.0679
	(.0401)	(.0399)			(.1042)	(.0999)
share of white-collar workers in region			.3019	.2591		
			(.3828)	(.3711)		
First Stage Fstat	43.12	43.12				
adj. R-sq	0.978	0.978	0.815	0.821	0.815	0.821
N	569380	569380	569380	569380	569380	569380
Additional Controls		y		y		y

Note: All specifications include the log number of white-collar and blue-collar workers, the log of capital stock and year-fixed effects. Specifications (2), (4) and (6) additionally control for individual plant-specific characteristics such as the industry and the age of the plant. Standard errors in parentheses are clustered at the region-year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

also correcting the bias in the coefficient of interest. Moreover, the decrease in the magnitude of the coefficient compared to the OLS estimate appears plausible, as the OLS estimate is most likely to be positively biased. Thus, the instrumental variable analysis of this paper provides more compelling estimates. In short, despite a sizable correlation, the effect of the regional human capital level on productivity decreases and becomes statistically insignificant when adopting my instrumental variable, which further corrects the positive bias. Thus, the results provide little support for the existence of human capital spillover beyond plant boundaries in Korea during the 1980s and mid-1990s.

I perform several robustness checks of the IV results. To begin with, I omit intermediate years when the impact of the reform was not fully realized and thus focus on the long-term effects of the policy. In particular, I exclude the years between 1986 and 1993 when the proportion of college graduates in the labor force was increasing steeply as young college graduates were replacing low-skilled workers. Panel A of Table 4 summarizes the estimation result omitting the intermediate years. The estimated effect of regional human capital on productivity is statistically indistinguishable from zero even after omitting the intermediate years.

Furthermore, I check whether the result is robust on different specification for measuring the relationship between human capital and productivity. In particular, I

turn to the total factor productivity (TFP) specification, measuring the TFP using the OLS method, after which I examine the whether this measure of productivity depends on the level of human capital in a given region.[11] To obtain the TFP measure, I regress the log of the value-added amount of the plant on labor input and on capital and then define the residual of the estimation as the TFP of a plant. The effect of the level of human capital on plant productivity based on the TFP can be summarized as the estimate of λ in the following equation:

$$TFP_{ijrt} = \lambda \overline{H}_{rt} + \boldsymbol{X}'_{ijrt}\Phi + d_j + d_r + d_t + v_{ijrt} \quad (6)$$

Panel B of Table 4 illustrates the results of an instrumental variable analysis using the TFP as an outcome variable. Again, consistent with the main results, the coefficient of the level of region human capital is small and statistically insignificant. Lastly, I use a more general functional form for the production function—a translog specification—instead of the Cobb-Douglas specification and estimate equation (5) including the square of each log input and the interaction between each log input. Panel C in Table 4 reports the results of the instrumental variable analysis under the translog production function. The coefficient of interest is somewhat sizable compared to the main specification but not statistically different from zero. Thus, this analysis shows that the main results are robust with regard to changes in the functional form of the production function.

VI. Conclusion and Discussion

In this paper, I examine the empirical significance local human capital spillover. In particular, I test whether plants located in regions with higher levels of human capital can produce more with a similar amount of input. To address endogeneity in regional human capital levels, I explore an educational reform in Korea which exogenously changed the level of human capital across regions by increasing existing differences in the supply of college graduates starting in the mid-1980s.

Using this exogenous change, I empirically estimate the relationship between the regional level of human capital and plant productivity. In particular, I explicitly control for endogeneity in the change in the level of human capital using an instrumental variable that utilizes the change in human capital induced by this reform. Overall, I find little evidence supporting the empirical significance of local human capital spillovers in Korea. That is, the productivity of a given plant in a given region is not affected by the level of human capital outside that plant after controlling for the plant's own human capital and other characteristics.

The results of this paper question the plausibility of human capital spillovers beyond plant boundaries.[12] Unlike human capital spillover inside a plant, it is not

[11]Because the data does not contains plant identifiers, I cannot use the methodology proposed by Olley and Pakes (1996) or Levinsohn and Petrin (2003), which controls for endogeneity in the labor and capital input more explicitly.

[12]It is important to note that this paper does not provide evidence that contradicts all types of human capital spillover. For instance, human capital spillover inside a plant or peer effects where workers are more likely to interact may still exist (Mas and Moretti 2009).

clear why skilled workers would teach their skills to those less skilled working in other establishments. That is, even if the workers interacted with workers in other plants, human capital spillover beyond plant boundaries is unlikely to occur, as skilled workers have little incentive to pass along their skills without being compensated for doing so.

There could be several other explanations for the relatively small degree of local human capital spillover in Korea. In particular, one may suspect that Korea is too small for the local human capital to exist in the first place. However, as Rosenthal and Strange (2008) document, the extent of the human capital spillover sharply decreases with distances, and most of the externalities stemming from face-to-face interactions are confined within five miles. Thus, it is less likely that the compact size of Korea would be a major factor affecting the small degree of local human capital spillover, as Korea is sufficiently larger than a five-mile radius and thus face-to-face interactions will depend on the location within the country. Other factors can include the long working hours in Korea during the 1980s and 1990s. Specifically, the long working hours in Korea—which often exceeded 2800 hours during the period analyzed in this paper—may have limited the opportunities for workers to interact with workers outside of their plants.

I would like to end this paper by providing several limitations of this work and a related caveat regarding any interpretation of the results. First, this paper does not examine the effects of local human capital spillover separately for each industry with different characteristics, such as the level of technological intensity. This limitation stems from the fact that the dataset does not contain appropriate instrumental variables that can address the endogeneity at the industry-region level. Thus, it is still possible that a specific manufacturing industry may have benefited from the increase in the human capital level of industries with similar characteristics. Furthermore, as human capital in the service sector is not accounted for in the model, this paper does not address the possibility of human capital in the service sector affecting the manufacturing productivity.

Finally, the result of this paper should not be interpreted as evidence that repudiates human capital externalities or human capital spillover in general. Specifically, the results here do not negate all types of human capital spillover. In particular, spillover within a plant where workers are more likely to interact with each other actively may exist. Likewise, human capital externalities that do not depend on physical distances, such as productivity enhancing from R&D, may have been a major source of human capital externalities during the 1980s and 90s in South Korea.

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Conflict in the Shadow of Conflict

By SE HOON BANG AND JAESOO KIM*

We study how an advantage given to an interim winner in sequential conflicts characterizes dynamic competition between players and influences their payoffs. As the intensity of competition during each period is negatively correlated, perfect security is not necessarily desirable for contending parties. We present results which are widely applicable to various types of dynamic competition, where competition in each period is linked to the interim winner's relative advantage. Policy implications are also discussed in a variety of areas, and several extensions are explored.

Key Word: Sequential Conflicts, All-Pay Auctions, Sequential Innovations, Arms Race
JEL Code: D44, D74, 031

I. Introduction

We often observe that conflicts or competition among economic agents are not easily concluded. In particular, if a prize awarded after a contest is not instantly secured, the competing parties may have to endure a series of conflicts afterwards. For instance, even if a tribe assails another tribe and appropriates a valuable resource, the invaded tribe may not simply relinquish the resource but may attempt to retake it.[1] Similarly, although a firm may succeed in developing a new innovation and earning a patent, rivals may be able to imitate the innovation unless the patent is ironclad. As a result, they expect that a patent holder will end up in litigation against potential imitators. Cumulative innovations are also a type of sequential conflict. Suppose that the development of commercial technology would not be possible without the findings of basic research. When identical firms compete for research first and for development second, weak protection for basic research would trigger competition for the second innovation.

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[1]A large body of literature exists on conflict and appropriation, where property rights are not perfectly enforced and economic parties are contesting insecure properties. See the excellent survey paper by Garfinkel and Skaperdas (2006) on the detailed development of research in this field.

In these examples, the characteristics of the subsequent conflict are significantly different from those of the initial conflict. Once the winning party securely holds the prize, the successive contest is no longer a "fair" competition but rather a battle between protecting and stealing.[2] In such a case, it is likely that the defensive party has is in an advantageous position than the offensive party in most cases. To capture this aspect, we incorporate a measure of the degree of defensibility or security against potential threats. This can be thought of as the strength of a patent against an imitation, or the degree of forward protection of a patent in an environment of cumulative innovations.

More generally, this is the first winner's relative advantage over her rival in the successive conflict, where she is favored in the next conflict given her higher winning probability. There are various types of dynamic competition in which the first winner has an advantage over a rival in subsequent contests. ICT industries, in which a large network effect prevails and/or switching costs exist, are good examples because an incumbent firm can enjoy a significant advantage in a subsequent contest. Moreover, considering sequential elections, a winner in an initial election often receives more media attention and financial support and will therefore have more opportunities to win in the next election. In these examples of dynamic competition, one can see that not only an immediate reward but also a relative advantage enjoyed by an initial winner subsequently can determine players' effort or investment levels during the entire contest.

This paper initially studies how the advantage created in sequential conflicts characterizes the dynamic competition between players and influences their payoffs. We develop a two- period model of dynamic competition which is based on the literature of conflict economics, where players are involved in a battle in which the prize is not secured immediately. We then show that the results are generally applicable to dynamic competition, in which the competition at each stage is linked to the interim winner's relative advantage in various aspects.

We start by demonstrating that the intensity levels of competition in the first period and in the second period are negatively correlated. If the property is perfectly defensible, agents fight only once in the first period. Not surprisingly, as the possibility of a second battle arises, agents play less aggressively in the first battle. In other words, as the property becomes less defensible, the intensity of competition is transmitted from the first period to the second. If it becomes perfectly non-defensible, they would fight only once, but in the second period.

Here, an interesting question is how the overall equilibrium competition, or more precisely the overall investment made by players, is characterized by the degree of defensibility. Although many types of dynamic competition have been studied, analyzing the overall competition over the long term from such a perspective has rarely been done. However, its importance cannot be disregarded, especially if one can manage dynamic competition to maximize contestants' total efforts over the periods in question.

First, we first show non-monotonic relationships between the overall equilibrium

[2]Grossman and Kim (1995) make a distinction between offensive weapons and defensive fortifications. Their main focus was to show how the full security of claims to property can be achieved. In contrast, we attempt to explain how imperfect security influences intertemporal competition during sequential conflicts.

investments and the degree of defensibility. In doing this, there are two different cases. If marginal competition decreases in the magnitude of the prize, the equilibrium level of the investments overall takes on an inverse U-shape with regard to the degree of defensibility, with a unique maximum at a particular degree of insecurity. In contrast, if marginal competition increases, the equilibrium level of overall investments is then pseudo U-shaped with a unique minimum.

The result in the former case implies that the overall intensity of competition becomes stronger if the interim winner has a relative advantage in dynamic competition. More importantly, from the perspective of a competition planner, it becomes possible to maximize the expected effort levels by selecting the optimal relative advantage or disadvantage of the first winner; i.e., it becomes possible to award a favor, or impose disfavor, on the first winner during the second period, depending on the nature of the competition. When the first winner rarely has an advantage in subsequent contests, giving him a favor boosts dynamic competition. In contrast, when the first winner has too much of an advantage in successive contests, removing some advantages can increase players' effort levels in an environment of dynamic competition. For example, in repeated procurements, an incumbent firm which won in the first period may have cost advantages by learning by doing or transferable investments in the second period. In such a case, an auctioneer prefers to remove the incumbent's advantages by requiring the winner to share information or the outcome of investments with rivals.

We also extend the model in several ways to show the robustness of our results and explore several other interesting implications. First, the basic result will hold when the interim winner has an advantage in payoffs. Second, we analyze n-period contests after which we investigate how uncertainty regarding the degree of security affects the intensity of competition in both periods. Last, we relax the assumption of winner-take-all competition. We believe that all of these extensions yield worthwhile results.

In the literature on optimal contests or all-pay auctions, there are a number of papers on how a contest designer can increase the overall level of investments of contestants in sequential contests. Baye, Kovenock and de Vries (1993) showed that is occasionally better for the seller to exclude some buyers in order to increase her expected revenue. Clark and Riis (1998) explored whether to distribute prizes sequentially or simultaneously. Gradstein and Konrad (1999) compared simultaneous contests and a series of pairwise contests. Moldovanu and Sela (2001) studied how prizes should be allocated and whether there should be one prize or more than two prizes depending on the shapes of cost functions.[3] However, our paper addresses this issue from the perspective of a designer who attempts to control a relative (dis)advantage of a previous winner so as to elicit maximum efforts from contest participants.[4] We also examine how this capability of a

[3]Many recent papers study optimal prize allocation rules in dynamic contests using experiments, including Cason *et al.* (2010) and Sheremeta (2010) among others. See Dechenaux (2015) for a more detailed survey in this area.

[4]Meyer (1991, 1992), in a dynamic setting, drew conclusions similar to ours when arguing that an optimal contract should have a positive bias. With the more general setting provided here, however, it should be negatively biased when the first winner has a sufficiently large advantage. Similarly, several implications of the findings by Laffont and Tirole (1988) are similar to those here, as they show that an incumbent with transferable investments should be favored at the reprocurement stage.

designer is related to the various tactics available to him, including the division of rewards, extending the contest periods, and imposing different degrees of uncertainty on the security of the prize.

The paper is organized as follows. In the next section, we explain the conflict technology and the setup of a basic model. We characterize equilibrium and analyze the results and then discuss applications of the model and its policy implications in Sections III and IV. In Section V, we extend the model in several ways to show the robustness of the results and investigate additional interesting findings. Section 6 concludes the paper.

II. Basic Model

Consider the following two-period model. There are two risk-neutral agents. Agent 1 and 2 contest an exogenous prize, *R*. This prize can be thought of as a newly found diamond mine, an increase in profits from developing a new technology, or a license for a new business. First, they choose the weapons level and fight against each other for the prize. The battle is a winner-take-all contest. Given that g_i and g_j represent the quantity of the arms, $p\left(g_i, g_j\right)$ denotes the probability that agent *i* becomes the winner to claim the entire resource. We employ the following function form for the technology of conflict.[5]

$$p\left(g_i, g_j\right)=\frac{f(g_i)}{f(g_i)+f(g_i)} \tag{1}$$

$f\left(x\right)$ is a non-negative and increasing; i.e., $f'/\left(x\right)\geq 0$. We also assume $f'\left(x\right)^2 > f''\left(x\right)f\left(x\right)$ to satisfy second-order conditions.[6] The symmetry in this conflict technology ensures fair competition. The result of the contest determines the interim winner and loser in the first period.[7]

Second, the loser has an opportunity to appropriate the prize from the winner. This consecutive contest is a battle between offense and defense. We continue to assume here that the battle is the winner-take-all contest such that the final winning agent can have perfect security about her prize. In this sense, payoffs from consuming the prize are realized at the end of the second period.[8] At this point, we

[5]This class of conflict technology has been employed in several studies, as is well summarized in Dixit (1987) and in Garfinkel and Skaperdas (2006). They also explain some of the main characteristics of this technology and compare it to other functional forms.

[6]This model satisfies a sufficient condition for the existence and uniqueness of equilibrium; the proof can be found in Skaperdas (1992).

[7]Indeed, our model is not directly applicable to R&D races, because innovation always takes place in the model of contest. However, we believe that our basic ideas and intuitions are applicable in various types of dynamic competition.

[8]Another way to understand this model is by considering that symmetric agents compete for the prize R_1 in the first period, and depending on the outcome of the first period, the favorable winner and unfavorable loser compete for R_2 in the second period. Our basic model is merely normalizing $R_1 = 0$. In fact, including interim payoffs does not change our basic results. In this sense, our model and results are relevant to explain other types of dynamic competition, even if they are not involved in contests with insecure prizes.

make the distinction between offense and defense such that defending the prize may be more effective than predating it given the same level of arms, or vice versa. We adjust the conflict technology in the following manner,

$$(2) \qquad q(w, l) = \frac{f(w)}{f(w) + \theta f(l)} \quad \text{and} \quad 1 - q(w, l) = \frac{\theta f(l)}{f(w) + \theta f(l)}$$

where $q(w, l)$ is the probability that the interim winner can keep the prize when w and l are respectively the winner's defensive weapons and the loser's offensive weapons. Likewise, $1 - q(w, l)$ is the probability that the loser can appropriate in the second battle. Note that θ is a parameter that indicates the effectiveness of the offensive weapons against the defensive weapons. If θ is smaller (greater) than 1, offense is less (more) effective than defense. Therefore, θ is a measure of the security of its claim to property once one agent owns the property after the contest of the first period. θ = 0 indicates a perfect property right. As θ increases, the property right becomes less strong. We will often refer to the inverse of θ as the degree of defensibility or security in the paper. Another interpretation of the degree of security is the relative advantage that the interim winner has over her rival in the successive battle. For simplicity, we assume that there is no discount and that the war is not destructive.

III. The Equilibrium Analysis

As usual, our analysis starts from the second period following backward induction. Once again, both battles are assumed to be winner-take-all contests. Regardless of who wins in the first period, the winner in the second period has fully secure property rights to the prize. Thus, the interim winner and loser payoff functions are given by

$$V_W = q(w, l)R - w \quad and \quad V_L = \left[1 - q(w, l)\right] R - l.$$

Each agent chooses the number of arms given its rival's choice. We obtain the following first-order conditions: $\frac{\partial V_W}{\partial_W} = \frac{\partial_q (w,l)}{\partial_W} R - 1 = 0$ and $\frac{\partial V_l}{\partial_l} = -\frac{\partial_q (w,l)}{\partial_l} R - 1 = 0$. Using (2), the first-order conditions are summarized as follows:

$$\frac{[f(w) + \theta f(l)]^2}{\theta f'(w) f(l)} = \frac{[f(w) + \theta f(l)]^2}{\theta f'(l) f(w)} = R.$$

According to these conditions, the winner and loser choose a symmetrical number of weapons for equilibrium regardless of θ. The symmetrical values of $w^*(\theta, R)$ and $l^*(\theta, R)$ must satisfy

$$\frac{f(w^*)}{f'(w^*)} = \frac{f(l^*)}{f'(l^*)} = \frac{\theta R}{(1+\theta)^2} \tag{3}$$

The given assumption of $f(x)$ ensures that $\frac{f(x)}{f'(x)}$ is non-decreasing. It can be easily shown that $w^*(\theta, R)$ and $l^*(\theta, R)$ are decreasing when $\theta > 1$ and increasing when $\theta < 1$. In other words, they invest in arms most when they are involved in fair competition, i.e., $\theta = 1$. The equilibrium probabilities and payoffs are as follows:

$$q(w^*, l^*) = \frac{1}{(1+\theta)} \quad \text{and} \quad 1 - q(w^*, l^*) = \frac{1}{(1+\theta)} \ ;$$

$$V_W^* = \frac{R}{1+\theta} - w^*(\theta, R) \quad \text{and} \quad V_L^* = \frac{\theta R}{1+\theta} - l^*(\theta, R).$$

First, it is important to note that $V_W^* = \left(\frac{1-\theta}{1+\theta}\right) R + V_L^*$. If $\theta < 1$, the winner's payoff is greater than the loser's payoff. In addition, it is expected that agents prefer to be the winner in the first battle. If $\theta > 1$, in contrast, the loser's payoff is greater. Agents are expected to prefer to be the loser in the first battle. That is to say, in the first battle, agents are willing to lose and therefore do not fight. In such a case, they wait and fight only once in the second period. Thus, hereafter, it is assumed that $\theta < 1$ for the rest of the discussion. It would be rather sensible to assume that the winner favors protecting his prize against the loser's attempt to steal it.

Given the second period outcome above, at this point we solve the following first-period problem. Each agent maximizes

$$V_i = p(g_i, g_j) V_W^* + [1 - p(g_i, g_j)] V_L^* - g_i,$$

where each agent obtains the winner's payoff with probability $p(g_i, g_j)$ and the loser's payoff with probability $1 - p(g_i, g_j)$. The first-order condition is $\frac{\partial V_i}{\partial g_i} = \frac{\partial p(g_i, g_j)}{\partial g_i}\left(V_W^* - V_L^*\right) - 1 = 0$. The incentive for investments in arms depends crucially on the difference between the winner's payoff and the loser's payoff. The

symmetrical equilibrium investments in arms, $g^* = g_i^* = g_j^*$ satisfy

$$\frac{f(g^*)}{f'(g^*)} = \begin{cases} \dfrac{V_W^* - V_L^*}{4} = \left(\dfrac{1-\theta}{1+\theta}\right)\dfrac{R}{4}, & \text{if } \theta \le 1, \\ 0, & \text{if } \theta \le 1. \end{cases} \tag{4}$$

One can immediately note that $g^*(\theta, R)$ is decreasing in θ, contrary to the effect of θ on $w^*(\theta, R)$ or $l^*(\theta, R)$. As the prize is more defensible in the future, agents fight more aggressively in the first battle. From (3) and (4) together, we find a well-known implication in the literature which holds that the levels of intensity of competition during the first and second battles are negatively correlated.[9]

Lemma 1 $\dfrac{\partial g^*(\theta,R)}{\partial \theta} < 0$ *and* $\dfrac{\partial w^*(\theta,R)}{\partial \theta} = \dfrac{\partial l^*(\theta,R)}{\partial \theta} > 0$. *As the property becomes less defensible, the first battle becomes less aggressive and the second battle becomes more aggressive.*

Let us analyze how the degree of defensibility influences the agents' overall equilibrium investments in arms, which is $g^*(\theta,R) + \dfrac{w^*(\theta,R) + l^*(\theta,R)}{2}$,

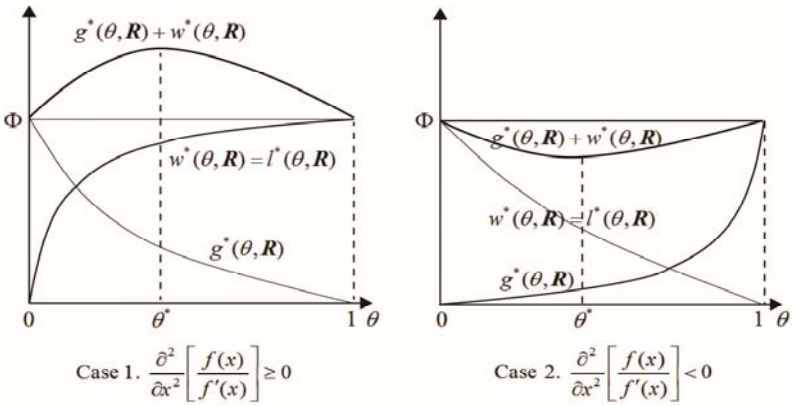

FIGURE 1

[9]This intuitive outcome is comparable to the literature on switching costs and customer poaching competition. When there are switching costs, a group of customers served by a firm in the first period is almost perfectly defensible as its source of profits in the second period. Firms in industries with switching costs compete very aggressively in the initial period, after which then they can attain a collusive outcome. See Klemperer (1987a). However, the literature on customer poaching explains the opposite situation. Roughly speaking, when competing firms expect aggressive customer poaching competition in the second period, they compete less aggressively in the first period. See Fudenberg and Tirole (2000) and Chen (1997).

i.e., $g^*(\theta,R)+w^*(\theta,R)$. We show below that this function is concave and has a maximum of $\theta\in[0,1]$.

Lemma 2 *If* $\frac{f(x)}{f'(x)}$ *is convex or linear, there exists a unique maximum* $\theta^*\in[0,1]$. *If* $\frac{f(x)}{f'(x)}$ *concave, there exists a unique minimum* $\theta^{**}\in[0,1]$.

The total investments in arms show a non-monotonic relationship in θ, and depend on how the marginal competition changes. If the marginal competition is nonincreasing with regard to the size of the prize, i.e., $\frac{\partial^2}{\partial x^2}\left[\frac{f(x)}{f'(x)}\right]\geq 0$, the overall competition is increasing as $\theta<\theta^*$ and decreasing as $\theta>\theta^*$.[10] The intuition for this result is as follows. For a relatively large degree of defensibility, the effect of a unit increase in investment in the first period is minimal on one's winning probability or payoff, because competition in the first battle is nearly saturated. The marginal return of investment is greater in the second battle. This is why competition in the second period is marginally more aggressive than in the first. A similar explanation is possible for a relatively small degree of defensibility. In contrast, if the marginal competition is increasing regarding the size of the prize, i.e., $\frac{\partial^2}{\partial x^2}\left[\frac{f(x)}{f'(x)}\right]<0$, this result dramatically changes in that the overall competition is now decreasing as $\theta<\theta^{**}$ and increasing as $\theta>\theta^{**}$.

In equilibrium, the two agents have an equal probability to receive the prize *R*, and they spend $g^*(\theta,R)+\frac{w^*(\theta,R)+l^*(\theta,R)}{2}$ to buy arms. The symmetric equilibrium payoff of each agent is as follows:

$$V^*(\theta,R)=\begin{cases}\frac{V_W^*+V_L^*}{2}-g^*(\theta,R)=\frac{R}{2}-\left[g^*(\theta,R)+\frac{w^*(\theta,R)+l^*(\theta,R)}{2}\right], & \text{if } \theta\leq 1,\\ \frac{R}{4}, & \text{if } \theta\leq 1.\end{cases}$$

[10] $\frac{f(x)}{f'(x)}$ is convex or linear in various types of functions. such as $f(x)=\ln x$ and $f(x)=x^{\alpha}$ for $0<\alpha\leq 1$.

Example 1 *For a simple example, we assume* $f(x) = x$ *for the technology of conflict. We can easily characterize the equilibrium as follows:* $w^* = l = \frac{\theta}{(1+\theta)^2} R$, $g^* = g_i^* = g_j^* = \left(\frac{1-\theta}{1+\theta}\right)\frac{R}{4}$, *and* $V^* = V_i^* = V_j^* = \frac{R}{4}\frac{3\theta^2+1}{(1+\theta)^2}$. *In this example,* $\theta^* = 1/3$. *Thus, at equilibrium, Payoffs are decreasing if* $\theta < 1/3$ *and increasing if* $\theta > 1/3$.

IV. Policy Implications and Applications

One of the main contributions of this paper is that it shows how the theoretic model and analysis of sequential conflicts presented in the previous section can be applied to a number of social and economic environments, from more direct types such as international arms races to quite subtle types such as R&D races among firms, the designs of procurement auctions, and even educational systems and structures, thereby providing valuable implications pertaining to many types of diplomatic, economic, and educational policies involved therein.

Note that the results summarized above tell us that the advantage created in sequential conflicts characterizes dynamic competition between players and influences the players' payoffs, where the prize the interim winner has obtained is not secure immediately but only has some advantages in later stages of the competition.

The finding that the overall competition or investment levels made by players are crucially affected by the degree of defensibility as well as the direction of changes in the marginal competition regarding the size of the interim prize has important implications on the optimal level of the interim winner's advantage. Whenever such a direction is positive, a contest planner would have to eliminate subsequent competitions which possibly arise thereafter by fortifying the security of the rewards given to an interim winner, if she wants to maximize the overall effort levels of the competing parties. If the direction is the other way around, the planner's strategy should be reversed as well.

The paper introduces a simple but robust result from a contest model, which has only been applied to very restricted areas such as military-relatedness issues. Nonetheless, the results indeed shed light on more extensive economic and social problems, including those shown hereafter. Firstly, there are many economic environments in which these results can have considerable implications. Provided that firms' R&D investment and innovation incentives are regarded as the most important factors for bringing economic development in a number of major technology-intensive industries, from information technology to the biotechnology industries, the optimal length and strength of patent protection to enhance innovation incentives among firms have always been a substantial issue. Similarly, with reference to repeated procurements, the optimal advantages given to incumbent firms and the level of information disclosure/sharing are also critical

issues.

Applying the implications of the results is as straightforward as it is useful. For instance, when considering an optimal educational policy as to the college admission process or any similar selection process of which the ultimate goal is to maximize students' effort levels during their pre-college years, the direction of changes in the marginal competition among students may be one of the factors at which the policymakers should closely examine.[11] This paper unfortunately does not show how such information can be acquired, as it is rather an empirical problem to do so. Nevertheless, it does indicate which aspect of students' behaviors should be taken into account and how they can be interpreted and used successfully to achieve policy goals.

Lastly, we provide various types of dynamic competition in which competition in each period is related according to the interim winner's advantage, and discuss the applicability of the results shown above. Unless specified, our discussions are based on the case where $\frac{f(x)}{f'(x)}$ is convex.

- *Insecure Prizes.* Nations and tribes in warfare buy more arms when winner's prize is not perfectly secure. When a sequence of innovations is undertaken by both firms, the firms invest more when the patent for the first innovation is not perfectly strong.
- *Repeated demands for bribes.* When a corrupt government official sells a license which is necessary to open a shop, he commonly demands more than once, threatening with the possibility of the replacement of the license owner.[12] Bribers can anticipate his repeated demands. In such a case, the possibility of a threat in the future is reducing θ from 0 in our model. This aspect can then increase the official's revenue. This result is in sharp contrast to that of Choi and Thum (2003), who studied the dynamics of corruption. In their model, both the dynamic consistency problem and intertemporal price discrimination undermine a corrupt official's revenues. The crucial difference in our model is incorporating competition between bribers.
- *Internal competition at companies.* Meyer (1992) studied biased contests for an organization's promotion decisions. The officer provides employees having shown high performance with more productive tasks, better work environments, or more opportunities for education and training.[13] This result is consistent with choosing the optimal θ^* in our model. However, while that model can show that a positive bias for the first winner minimizes the

[11]Once this factor is specified and clarified, it would greatly help policymakers to reach proper decisions about, for example, whether to allow a college to discriminatorily evaluate applicants according to the performance and reputation of the high school from which they are graduating, as this policy and regulation is closely related to the "interim winner's advantage."

[12]Choi and Thum (2004) introduce several examples or repeated extortion in bribes, organized crime, and expropriations of multinational corporations.

[13]"For example, at 3M, divisions and even groups purposefully compete with one another. At Bloomingdale's, the merchandising vice president, buyers, and fashion coordinators engage in an unending tussle for scarce floor space. The company reorganizes regularly as both winners and losers emerge." — Peters and Waterman (1988)

principal costs, our model represents the uniqueness and magnitude of optimal bias.

- *Learning by doing during repeated procurement.* This issue was studied by Lewis and Yildirim (2002), especially with the example of the repeated purchases of weapon systems, aircraft, and missiles by the Department of Defense. Our model suggests that the principal can prefer handicapping the first winner, who is now more efficient at the reprocurement stage, by information sharing.
- *Property rights and R&D incentives.* Reinforcing property rights is not necessarily desirable for the winner. When $\theta > \theta^*$, her equilibrium payoff decreases as the degree of defensibility rises, i.e., as θ falls. If this is the case, interestingly, contending agents prefer to remain in an insecure situation. The result is reminiscent of Gallini (1992) and Choi (1998) in the imitation literature. They have shown that a longer patent lifetime or a stronger patent does not necessarily increase an innovator's payoff. They came to this result after correspondingly incorporating costly imitation and strategic information transmission through patent litigation. We come to the same conclusion when allowing for repeated innovation by the same firm. Another slight difference is that they investigated *ex-post* innovator's incentives while this paper studies agents' *ex ante* incentives prior to competition.
- *Dynamic competition with switching costs.* The literature on switching costs is comparable to the second case in which marginal competition increases. Klemperer (1987a) basically showed the equivalence of the two extreme cases of $\theta = 0$ and $\theta = 1$. When switching costs exist, the second period competition nearly vanishes in that competing firms are able to achieve a collusive outcome. However, price wars in the first period compete away all of the expected rents in the second period. However, Klemperer (1987b) demonstrated how overall competition could be weakened when there is a group of new consumers in the second period. The portion of new consumers corresponds to θ in our model. They are not defensible for the successive competition as a source of the firms' profits, whereas old consumers whose preferences are constant are locked in. One can find that price competition in his model marginally increases, which is the driving force for the result.[14]

[14]Indeed, the model by Klemperer (1987b) is more elaborate than our simple description above. It has another group of old consumers whose preferences in the second period are independent of their first period tastes. More importantly, consumers' expectations about future prices are crucial to the results. In fact, his focus was on showing that competition in both periods could be relaxed when consumers have rational expectations. Nonetheless, it is true that overall competition is mitigated when consumers are myopic.

V. Extensions and Discussions

In this section we extend the model several ways to realize further implications about sequential conflicts. In each extension, to isolate the implication of each case, we retain the others.

A. *Payoff Advantage*

Thus far, we assume a relative advantage for the interim winner by way of a more effective defense against offense in conflict technology. Here, we study another way by which the interim winner is favored to gain the final payoff. The second competition is now assumed to be fair in that $q(w, l)=\frac{f(w)}{f(w)+f(l)}$. However, the final winner receives $(1-\theta)R$ securely, while only θR is contestable. The repeated winner is able to obtain an additional gain by $(1-\theta)R$ when she finally wins in the successive contest. Alternatively, this situation can be interpreted as meaning that the loser may be able to appropriate only a portion of the prize. Thus, the inverse of θ continues to represent defensibility. The interim winner and loser's payoff functions are given by

$$V_W=\frac{f(w)}{f(w)+f(l)}\theta R+(1-\theta)R-w \text{ and } \mathrm{V}_L=\left(\frac{l}{w+l}\right)\theta R-l.$$

From the first-order condition and $V_W-V_L=(1-\theta)R,$ it is straightforward to obtain $\frac{f(g_i^*)}{f'(g_i^*)}=\frac{f(g_j^*)}{f'(g_j^*)}=\frac{1-\theta}{4}R.$ Again, only the second battle arises when $\theta=1,$ whereas only the first battle occurs when $\theta=1.$ At this point, the expected overall competition is characterized by the following proposition.

Proposition 1 (1) *If* $\frac{f(x)}{f'(x)}$ *is convex, there exists a unique maximum* $\theta\in[0,1]$. (2) *If* $\frac{f(x)}{f'(x)}$ *is linear,* $\frac{\partial}{\partial\theta}=\left[g^*(\theta,R)+\frac{w^*(\theta,R)+l(\theta,R)}{2}\right]=0.$ (3) *If* $\frac{f(x)}{f'(x)}$ *is concave, there exists a unique minimum* $\theta^{**}\in[0,1].$

A contest designer can increase contestants' total effort levels by (dis)favoring the first winner during the payoff. Hence, our basic results are robust given this type of advantage. Moreover, this extension provides unique implications about how to allocate the prize in sequential contests. In fact, the setup can be viewed as the contest designer's decision to distribute a single prize by the proportion of

$1-\theta$ and θ in sequential contests. In other words, one can see that $(1-\theta)R$ and θR are merely the payoffs in the first stage and second stage, respectively. In this case, when the marginal competition decreases, a sequential distribution can raise contestants' efforts levels.

This result is worthy of comparison to Clark and Riis (1998), who studied whether to distribute multiple prizes simultaneously or sequentially, and Moldovanu and Sela (2001), who compared the expected sum of efforts by a single prize and by more than two prizes. One important assumption in both papers was that contestants have different abilities. In our model, however, we show that the contest designer can increase the effort level through sequential competition between equally capable contestants.

B. *n-period Model*

One natural question is how the outcome would be if we extend the model to *n*-period contests. When players engage in more battles, do they fight more vigorously? Does a principal want to make sequential contests longer? We answer all of these questions. For analytical simplicity and tractability, we follow the example above for the remainder of the paper.

Suppose that two competing agents fight against each other *n* times to win a prize. The first battle is a fair competition, whereas the successive battles involve protecting and stealing. We solve this game by backward induction. The last *n*-th period game is no more than one in a two-period game. The winner and loser in the $(k-1)$-th period maximizes the following payoff functions, respectively, where $3 \le k \le n$.[15]

$$V_{K-1,W} = q(w_{k-1}, l_{k-1})V^*_{K,W} + (1-q(w_{k-1}, l_{k-1}))V^*_{K,L} - w_{k-1}$$

(5) and

$$V_{K-1,L} = (1-q(w_{k-1}, l_{k-1}))V^*_{K,W} + q(w_{k-1}, l_{k-1})V^*_{K,L} - l_{k-1}$$

Again, the incentive for investments in arms depends on the difference between the winner's payoff and the loser's payoff in the next period. Thus, the number of arms to ensure equilibrium in the $(k-1)$-th period is represented as follows:

$$w^*_{k-1} = l^*_{k-1} = \frac{\theta}{(1+\theta)^2}\left[V^*_{k,w} - V^*_{k,L}\right]$$

Putting this into the payoff functions in (5), we can derive the relationship between the equilibrium payoffs of the $(k-1)$ - th and the *k*-th periods.

[15]We assume for n-period extension that either θ or *n* is not sufficiently large. This guarantees positive payoffs at equilibrium. This is a trivial issue because this assumption can be avoided easily with including interim payoffs.

(6) $$V^*_{K-1,W} - V^*_{K-1,L} = \frac{1-\theta}{1+\theta}\left[V^*_{K,W} - V^*_{K,L}\right]$$

This implies that $\left[V^*_{k\text{-}1,W} - V^*_{k\text{-}1,L}\right] < \left[V^*_{k,W} - V^*_{k,L}\right]$. As a result, the equilibrium level of investments in arms is greater in the successive battle. That is to say, $w^*_{k\text{-}1} - l^*_{k\text{-}1} < w^*_k - l^*_k$. The following proposition summarizes the effects of long periods of battle on the overall competition over *n* periods and agents' *ex ante* equilibrium payoffs.

Proposition 2 *The overall equilibrium investment in arms is as follows*:

$$g^*_i + \sum_{k=2}^{n} \frac{w^*_k + l^*_k}{2} = \left[\frac{1+\theta}{2\theta} - \left(\frac{1-\theta}{1+\theta}\right)^{n-2}\left(\frac{2+\theta}{4\theta}\right)\right]\left(\frac{1-\theta}{1+\theta}\right)R + \frac{\theta}{(1+\theta)^2}R, \; n \geq 2.$$

As n increases, the overall equilibrium investment in arms rises and agents' payoffs fall.

One implication of this result is that the principal can increase players' effort levels by extending the contest periods. Of course, some costs may be incurred when extending the contest periods. For example, internal competition which is too aggressive hampers cooperative work among workers. Thus, the principal may want to choose the optimal number of periods.

C. *Uncertainty of Defensibility*

The degree of security or defensibility, θ, has been assumed to be certain thus far. Here, we are going to assume it away and study how uncertainty of θ influences agents' arms races and payoffs. Here, θ is a random variable that may follow either $H_1(\theta)$ or $H_2(\theta)$. H_2 entails a riskier second period battle than $H_1(\theta)$ in the sense that $H_2(\theta)$ is the mean preserving spread (MPS) of $H_1(\theta)$.[16]

At this stage, we must solve the maximization problem of expected payoffs for each agent in each period. Risk neutrality allows the expected payoff to be additively separable. Given the functional form, it is straightforward to obtain the following result.

[16]That is, for $\theta \in [0,1]$ and $\int_0^1 \theta h_1(\theta)d\theta = \int_0^1 \theta h_2(\theta)d\theta$, $\int_0^\theta H_1(x)dx \leq \int_0^\theta H_2(x)dx$.

$$E(w^*) = E(l^*) = E\left(\frac{\theta}{(1+\theta)^2}\right)R,$$

(7)
$$E(g^*) = E(g_i^*) = E(g_j^*) = \frac{R}{4}E\left[\frac{1-\theta}{1+\theta}\right],$$

$$E(V^*) = E(V_i^*) = E(V_j^*) = \frac{R}{4}E\left[\frac{3\theta^2+1}{(1+\theta)^2}\right].$$

Proposition 3 *As a situation becomes more risky, the more aggressive the first period battle is, and the less aggressive the second period battle becomes, which is also true for the overall competition.*

The effect of the MPS depends on the concavity or convexity of each of the functions. Given that the values of $w^* = l^*$ are concave in θ, the MPS decreases with regard to its expectation. In contrast, g^* and V^* are convex and their expectation levels increase due to the transformation of the MPS. The intuition behind this result is simple. A more risky battle makes it more important to have a winner's advantage in the second period. Thus, competing agents compete more aggressively in the first battle. In turn, this aggressive competition reduces the intensity of the competition in the second period. In addition, the second period competition dominates the first period competition by $w^* = l^* > g^*$. As a result, agents are better off when they are involved in a more risky battle.

D. *Relaxing the Winner-Take-All Principle*

We have assumed that contests are winner-take-all competitions. This assumption appears to be rather strong and inappropriate in the context of sequential innovation or imitation. However, relaxing this assumption does not change our basic results. In contrast, we find that contending parties compete more aggressively. The intuition here is simple as well. Unless the battle is a winner-take-all competition, they share the prize according to the proportion of $p(g_1, g_2)$ and $1-p(g_1, g_2)$ after the first battle. In the second battle, they have to protect their own property and attempt to appropriate the rival's property at the same time. Put differently, they compete on two fronts. This makes the first battle more aggressive, making use of relative advantage more on one's front and reducing losses from the relative disadvantage on one's rival's front.

Proposition 4 *The first battle becomes more aggressive if the conflict is not a winner - take - all contest.*

VI. Concluding Remarks

We have developed a simple dynamic model of sequential conflicts. The basic premise of the paper is that contending parties expect ensuing conflicts because properties are not perfectly secure even after engaging in a contest once. We have demonstrated how the degree of insecurity characterizes the dynamic competition in successive contests. We then explored how the contest designer wants to control the relative (dis)advantage of the initial winner in order to maximize all players' overall effort levels, and how the results are related to the several techniques that the contest designer can employ, such as the dividing the prizes, extending the periods of contest, and imposing uncertainty on the security of the prize.

A deficiency of the paper is that it does not analyze social welfare, especially in the context of sequential innovation, because innovation always takes place in our model. For instance, Denicola (2000) studied the socially optimal level of patent protection in an environment of sequential innovation, comparing four different regimes according to whether the second innovation is patentable and infringing. The focus of that paper was to investigate how the patent breadth should be chosen from the perspective of social welfare.[17] In contrast, the present study focuses on characterizing dynamic competition and its implications, being based on more general settings in which various types of sequential conflicts can be analyzed.

Appendix

The Proof of Lemma 2.

Applying the implicit differentiation to (3) and (4), $\frac{\partial}{\partial\theta}\left[g^*(\theta,R)+w^*(\theta,R)\right]\gtreqless 0$ can be rearranged as follows:

$$\frac{F'(w^*)}{F'(g^*)}\lesseqgtr\frac{2(1-\theta)}{(1+\theta)}.$$

Here, $F(x)=\frac{f(x)}{f'(x)}$. Note that the inequality above holds when $\theta=0$ while the inequality below holds when $\theta=1$. Because the right-hand side is decreasing in θ, as long as the left-hand side is non-decreasing in θ, θ^* exists and is unique. One can show that the derivative of $\frac{\left[F'(w^*)\right]}{\left[F'(g^*)\right]}$ with respect to θ is non-negative when $F''(x)\geq 0$. The other case can be proven similarly.

[17]Green and Scotchmer (1995) argued that the first patent should be very broad to provide the first innovator with sufficient incentives to invest when different firms undertake a sequence of innovations. However, both this paper and that by Denicola (2000) consider cases in which the same firms compete for repeated innovations.

The Proof of Proposition 1.

The proof here is very similar to that of Lemma 2. $\frac{\partial}{\partial\theta}\left[g^*(\theta,R)+\frac{w^*(\theta,R)+l^*(\theta,R)}{2}\right]\gtreqless 0$ can be written as $\frac{F'(g^*)}{F'(w^*)}\gtreqless 1$. Using $g^*(1,R)=w^*(0,R)=0$ *and* $g^*(0,R)=w^*(1,R)=\Phi$, it is straightforward to show the existence of θ^*. The concave $F(x)$ ensures that $\frac{F'(g^*)}{F'(w^*)}$ is decreasing.

The Proof of Proposition 2.

$$g_i^*+\sum_{k=2}^{n}\frac{w_k^*+l_k^*}{2}$$

$$=\frac{1}{4}\left[V_{2,W}^*-V_{2,L}^*\right]+\frac{\theta}{(1+\theta)^2}\left[V_{3,W}^*-V_{3,L}^*\right]+\cdots+\frac{\theta}{(1+\theta)^2}\left[V_{n,W}^*-V_{n,L}^*\right]+\frac{\theta}{(1+\theta)^2}R$$

Because $\left[V_{k,W}^*-V_{k,L}^*\right]=\left(\frac{1-\theta}{1+\theta}\right)^{n-k}\left[V_{n,W}^*-V_{n,L}^*\right]$ by (6), solving the geometric sequence gives us

$$\sum_{k=2}^{n-1}\frac{w_k^*+l_k^*}{2}=\frac{1-\left(\frac{1-\theta}{1+\theta}\right)^{n-2}}{1-\left(\frac{1-\theta}{1+\theta}\right)}\left[V_{n,w}^*-V_{n,L}^*\right]$$

$$=\frac{1+\theta}{2\theta}\left[1-\left(\frac{1-\theta}{1+\theta}\right)\right]^{n-2}\left[V_{n,w}^*-V_{n,L}^*\right].$$

In addition, $g_i^*=\frac{1}{4}\left[V_{2,W}^*-V_{2,L}^*\right]$ can be rewritten by $\frac{1}{4}\left(\frac{1-\theta}{1+\theta}\right)^{n-2}\left[V_{n,W}^*-V_{n,L}^*\right]$. Thus, we have

$$g_i^*+\sum_{k=2}^{n}\frac{w_k^*+l_k^*}{2}=\left[\frac{1+\theta}{2\theta}-\left(\frac{1-\theta}{1+\theta}\right)^{n-2}\left(\frac{2+\theta}{4\theta}\right)\right]\left[V_{n,w}^*-V_{n,L}^*\right]+\frac{\theta}{(1+\theta)^2}R.$$

Finally, we substitute $\left[V_{n,w}^*-V_{n,L}^*\right]$ by $\left(\frac{1-\theta}{1+\theta}\right)R$.

The Proof of Proposition 3.

Consider any function $v(\theta)$ which is either convex or concave. Via integration by parts twice, we obtain

$$E_{H_1} v(\theta) - E_{H_2} v(\theta) = \int_0^1 v(\theta) d(H_1(\theta) - H_2(\theta))$$

$$= \int_0^1 \left(H_2(\theta) - H_1(\theta)\right) v'(\theta) d\theta$$

$$= -\int_0^1 \int_0^\theta \left(H_2(\theta) - H_1(\theta)\right) v'(\theta) d\theta$$

Thus, the sign depends crucially on $v''(\theta)$. $E\left[v\left(\theta\right)\right]$ is greater (smaller) in $H_1\left(x\right)$ if $v(\theta)$ is concave (convex).

The Proof of Proposition 4.

After the first battle, agents 1 and 2 hold $p\left(g_1,\, g_2\right)R$ and $\left(1 - p\left(g_1,\, g_2\right)\right)R$, respectively. Hence, each agent engages in offense and defense in the second battle. Following the first-order condition (3), each agent's choice of investment about the property of agent 1 is $w^* = l^* = \dfrac{\theta}{\left(1+\theta\right)^2} P(g_1, g_2)R$ and that of the property of agent 2 is $w^* = l^* = \dfrac{\theta}{\left(1+\theta\right)^2}\left(1 - P(g_1, g_2)\right)R$. The sum of the two is $\dfrac{\theta}{\left(1+\theta\right)^2}R$, which is identical to a winner-take-all competition. Each agent's equilibrium payoff in the second battle can be written by follows:

$$V_{2,1} = \frac{1}{(1+\theta)^2} p(g_1, g_2)R + \left(\frac{\theta}{1+\theta}\right)^2 \left(1 - p\left(g_1, g_2\right)\right)R \text{ and}$$

$$V_{2,2} = \frac{1}{(1+\theta)^2}\left(1 - p\left(g_1, g_2\right)\right)R + \left(\frac{\theta}{1+\theta}\right)^2 p(g_1, g_2)R.$$

In the first battle, agent 1 maximizes $p(g_1, g_2)V_{2,1} - g_1$ and agent 2 maximizes $\left(1 - p\left(g_1,\, g_2\right)\right)V_{2,2} - g_2$ at the same time. The symmetric outcome is

$g_1^* = g_2^* = g^* = \frac{R}{4(1+\theta)^2}$. This is greater than (4) in a winner-take-all competition.

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