Hi-Tech. Company Surviving in High Compete Environment

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ABSTRACT

As the barriers to international trade melt away and globalization both deepens and proliferates, competition intensifies. Focusing on competition within high technology industries, this study argues that the key to surviving competition and overcoming the challenges of globalization lies in innovation. To establish this argument, two high technology industries are used as case studies: the computer and the telecommunications industry.

R&D is the key to technological innovation and innovation, in turn, is the basis upon which corporations cement their market presence and expand their market shares. While the historical importance of innovation in high technology industries has always been incontrovertible, globalization has maximized its importance. The reason, quite simply, lies in that the intensification of competition translates into the maximization of the importance of innovation as the key to market survival. Having established the aforementioned, the study looks towards the role of both domestic and foreign research and development in promoting US high technology industries. Employing the Grossman and Helpman theoretical models, the study undertakes a comprehensive exploration of the named industries for the purposes of determining the role of foreign investment and knowledge in motivating and promoting domestic R&D and ensuring that the US computer and technology industries retain a pronounced presence in international markets.
Keywords: *High-technology industry, R&D, Innovation.*

INTRODUCTION

In the global economy, innovation in high-technology industries is influenced by both foreign and domestic challenges and opportunities. A critical issue in technology policy is how globalization affects innovation. An effective domestic technology policy must address the question of how the interaction between domestic and foreign conditions influences domestic innovation. In particular, this study addresses the need to better understand the role of international knowledge flows and absorptive capacity in innovation at the detailed industry level by examining these relationships in four distinct high-technology industries.

The empirical work here builds on the theoretical framework of Grossman and Helpman (1991a), which links domestic productivity to investment in R&D and to international trade at the country level. One dynamic, high-technology industries that rely heavily on investment in research and development (R&D) is studied: computer equipment (SIC 357) which represents a range of technological maturity and competitiveness on the global stage, facilitating an investigation of the multifaceted relationship between globalization and domestic innovation. This study addresses these gaps in three significant ways. First, the analysis is carried out at a level of industry detail which allows much greater insight into this relationship in a range of U.S. high-technology industries. Second, this research considers the role of both imports and exports as channels of international knowledge transmission. Third, this analysis uses the broad spectrum of industries to consider how the relative strength of the domestic industry compared to its foreign counterpart relates to domestic innovation.

Ultimately the results of the analysis in this study suggest that the interaction of domestic capabilities, foreign R&D, and international trade matter for domestic innovation. These findings highlight the intertwining of domestic and foreign innovation and the importance of considering domestic innovation in a global context.

INVOVATION AND TECHNOLOGICAL CHANGE

Fundamentally, innovation depends on developing and finding knowledge and embodying it in new or better products or processes. Importantly, innovation involves knowledge flows. Rather than a unidirectional, one-time occurrence of transfer of basic scientific knowledge to application, the processes of innovation and knowledge transfer are complex and interactive ones, in which a sustained two-way flow of information is critical. (Mowery and Rosenberg, 1989, p.8)

Knowledge flows are a mix of efficient and highly, often deliberately, inefficient mechanisms. Technical knowledge comprises three quite different parts: (1) knowledge made available to users through the codified scientific and engineering literature; (2) proprietary knowledge, which is codified and protected from diffusion by mechanisms including trade secrets; and (3) the “tacit knowledge” that arises from “learning by doing.”

Not surprisingly, R&D is essential to both creating knowledge and absorbing it. Absorptive capacity is an important component of R&D spillover; spillovers are more likely to occur if the "receiver" is advanced enough to find new knowledge, recognize its importance, and otherwise prepared to incorporate this knowledge effectively. At the same time, the flow of knowledge is not unimpeded; mechanisms that mitigate the flow of knowledge from the entity that invested resources in innovation include trade secrets and other intellectual property restrictions. Innovation has become increasingly decentralized, with the importance of central R&D laboratories of large companies decreasing. Firms have become more reliant on outside sources of technology which involves relationships with foreign as well as domestic firms (Branscomb and Florida, 1998).

It is generally acknowledged that there are barriers to the transnational transmission of knowledge, including variations in absorptive capacity; in this case, R&D abroad would not be as useful to domestic innovation as R&D at home. Within a nation knowledge diffuses most quickly within a limited geographic range due to the importance of personal contact and other aspects facilitated by proximity (Jaffe, 1993; Mansfield, 1995). Other studies also find that the degree of technological similarity affects the flow of knowledge. Looking at the U.S. and Japan, Branstetter (1996) finds that foreign R&D has a greater impact on firm level innovation the closer the patent portfolios are. The results of these studies suggest that knowledge flows between nations, but that this is neither complete nor automatic. The relationship between imports and domestic innovation is discussed in light of the literature on import competition. The following section discusses the role of exports. These considerations will be critical aspects of the analysis presented in this study.

Exporting grants access to a larger market, allowing greater economies of scale and potential gains in TFP. Exporting might also facilitate knowledge spillovers, through contact with foreign R&D, which increases the cumulative stock of knowledge available. However, knowledge spillovers are likely to be bidirectional, i.e. knowledge might flow out as well as in, potentially proving detrimental. This might be particularly true with a technically sophisticated market.

Empirical evidence on the relationship between exporting and TFP is mixed. At the firm level, Bernard and Jensen (1999) find little evidence that exporting leads to increased TFP performance, although they do find evidence that more productive firms are more likely to export. On the other hand, Lawrence (2000) finds a negative relationship between TFP growth and exports in U.S. manufacturing at the pooled three-digit level.

INDUSTRICAL COMPETITIVENESS AND REVEALED COMPARATIVE ADVANTAGE

In this study, competitiveness enters into the discussion as a means for characterizing the “strength” or “weakness” of the industries. In particular, competitiveness helps explain how international trade and technology might interact differently depending on the trade position.

While export shares can tell us about the competitiveness of individual industries, relative shares allow us to examine the distribution among the industries. It is reasonable to postulate that the relationship between trade and innovation might be different in an industry that has comparative advantage than in an industry which does not. One way to do this utilizes the work of Balassa in developing the idea of revealed comparative advantage. Following Balassa, revealed comparative advantage is calculated as:

$$RCA_i = \frac{US\,x_i}{world\,x_i} \bigg/ \frac{US\,x}{world\,x} * 100$$

where USx_i= U.S. exports in industry i and $world\ x_i$= combined exports from the European Union, Japan, and the U.S. in industry i. Likewise, *US x* and *world x* are, respectively, the U.S. and combined European Union, Japan, and U.S. exports in all goods.

A revealed comparative advantage value above 100 means that the U.S. has a larger share in world exports in this industry than it does in total exports of all goods. Conversely, a revealed comparative advantage below 100 means that the U.S. has a smaller share in world exports in this industry than it does in total exports of all goods.

EMPIRICAL FRAMEWORK

Hypothesis

What is the relationship between domestic innovation and interaction with technically sophisticated trade partners? The previous discussion suggests several hypotheses about the plausible relationship between R&D, international trade, and domestic innovation in high-tech industries. These hypotheses are outlined below.

1. *Domestic R&D enhances domestic innovation.* Domestic investment in R&D should lead to gains in TFP performance.
2. Foreig*n R&D may enhance or discourage domestic innovation.* It is more likely that foreign R&D will be somewhat less helpful to the U.S. industry. There are a number of reasons why this might be, including geographic barriers, language differences, local specificity of knowledge, and research redundancy. Foreign R&D should have a positive relationship to domestic innovation in industries which are strong and where foreign R&D is significant.
3. Imports may enhance or discourage domestic innovation. Imports might also allow domestic firms to effectively exercise their comparative advantage in other areas, maintaining high productivity by relying on low cost imports in non-critical areas of the product line. On the other hand, import competition in finished goods might prove deleterious to a weak domestic industry if it cannot compete in price or quality. The consequences of this situation might be a productivity decrease and plausibly the contraction or loss of the domestic industry.
4. Exports may enhance or discourage domestic innovation. This could take the form of scale effects from increased market size, including greater efficiencies, as well as greater opportunity for learning by doing. As well, more general learning through exporting might occur essentially as a by-product of engaging in trade. On the other hand, there is also the possibility of knowledge flowing to competitors, which might prove harmful to domestic industry performance in the future.

CONCEPTUAL FRAMEWORK AND MODEL

In the Grossman and Helpman (GH) model, innovation occurs through investment in R&D, which results in an increase in either the number or the quality of available intermediate goods for the production of final products. International trade allows access to the cumulative stock of knowledge beyond domestic borders; thus, the cumulative stock of knowledge increases with the cumulative volume of international trade.

Grossman and Helpman Framework

In the GH model, investment in R&D leads to new varieties of intermediate and simultaneously contributes to the cumulative stock of knowledge due to knowledge spillovers. International trade contributes to TFP growth by expanding the pool of cumulative knowledge stock, as embodied in the increasing number of differentiated inputs available globally. In the simplest form final goods are produced by a Cobb-Douglas production function with constant returns to scale using labor and intermediate inputs:

$$Y = AD^{\beta} L^{1-\beta}$$

where *A* is the rate of technological progress, or the productivity parameter; D is an index of differentiated intermediate inputs; and *L* is labor. Economic growth in this model occurs through an increase in total factor productivity (TFP). Differentiated intermediate goods are produced with common, constant returns to scale production function:

$$D = \left[\int_0^n x(j)^{\alpha} \, dj \right]^{1/\alpha} , \quad 0 < \alpha < 1$$

where D is a single homogeneous consumption good assembled from intermediate inputs*).* If X = *xn* resources are used in production of each final good, then the production function can be expressed as:

$$D = x\, n^{1/\alpha}$$

and TFP increases as the number of varieties, *n,* increases:

$$\frac{D}{X} = n^{(1-\alpha)/\alpha}, \qquad 0 < \alpha < 1$$

Each new variety is created by devoting *a* unit of labor to R&D for time *dt*, or:

$$\dot{n} = \frac{L}{a}$$

In the steady state, the economy grows at the rate of introduction of new varieties of intermediates:

$$g = \frac{\dot{n}}{n}$$

Knowledge stock can be assumed to be directly proportional to the number of intermediates, n, and expressed:

$$K = n$$

Knowledge contributes directly to creating "blueprints" for new intermediates, which can be appropriated by the producer (e.g., through patenting or other means).

When there is knowledge spillover, the existing stock of knowledge is also augmented. Thus,

$$\dot{n} = \frac{K\,L}{a}$$

New intermediates thus are developed by utilizing - units of labor to produce each *K* intermediate.

Thus, trade introduces new incentives for the country that starts out more advanced to introduce more new product varieties (innovate), while the slower country faces diminished incentives to innovate. In particular, foreign R&D could be associated with more sophisticated competitors, which can have both positive and negative impacts on domestic innovation beyond the increase in available knowledge stock. While the GH framework lays out the importance of exports as well as imports in international knowledge transmission, the empirical work to date has primarily focused on imports.

SPECIFICATION AND DATA

Specification

The model that is used to explore the industry level relationship between TFP, domestic and foreign R&D, and international trade is related to the Grossman and Helpman framework described in the previous section .The specification which is estimated is:

$$\ln tfp3_i = \beta_0 + \beta_1 \cdot \ln rdst_i + \beta_2 \cdot \ln frdst_i + \beta_3 \cdot expsal\_1_i + \beta_4 \cdot impsal\_1_i + \beta_5 \cdot (expsal\_1_i) \cdot (\ln frdst_i) + \beta_6 \cdot (impsal\_1_i) \cdot (\ln frdst_i) + \beta_7 \cdot time + \varepsilon$$

where i= 1,2,3,4 is the index of the four three-digit industries considered in this dissertation. The time variable, *time* is included to minimize the effects due primarily to a common trend over time.

Table below summarizes the interpretation of the interactive coefficients in this model. In the top right quadrant the effect of trade is negative, but as there is more knowledge to tap into abroad, i.e. as the level of foreign R&D increases, then this can begin to dominate and the real effect of trade might have a positive relationship to TFP. On the other hand, the lower left quadrant *represents* the situation where trade might have a positive relationship to TFP. However, as the level of foreign R&D increases, the technical sophistication of foreign competition increases.

	β_3 or β_4 >0	β_3 or β_4 < 0
β_5 or β_6 >0	$\frac{\partial \ln TFP}{\partial trade} > 0$	$\frac{\partial \ln TFP}{\partial trade}$ ambiguous, depends on *lnfrdst*
β_5 or β_6 >0	$\frac{\partial \ln TFP}{\partial trade}$ ambiguous, depends on *lnfrdst*	$\frac{\partial \ln TFP}{\partial trade} < 0$

Expectations on the coefficients in the equation:

$$\ln tfp3_i = \beta_0 + \beta_1 \cdot \ln rdst_i + \beta_2 \cdot \ln frdst_i + \beta_3 \cdot expsal\_1_i + \beta_4 \cdot impsal\_1_i + \beta_5 \cdot (expsal\_1_i) \cdot (\ln frdst_i) + \beta_6 \cdot (impsal\_1_i) \cdot (\ln frdst_i) + \beta_7 \cdot time + \varepsilon$$

Data and Estimation

The equation is estimated using industry level data on U.S. imports and exports, domestic R&D, and foreign R&D to address these questions in the industry in question. Domestic and foreign R&D stock variables are created using the perpetual inventory method. Foreign R&D stock is calculated from total R&D performed by industry in the European Union and Japan.

COMPUTER EQUIPMENT INDUSTRY

The importance of continued investment in R&D as a driver of innovation and as a contributor to endurance in the global arena is particularly apparent in the case of this robust industry. Key characteristics include the role of international linkages and competition in the picture of the evolving industry, and the domestic industry's response and adaptation to competitive pressures. The empirical results suggest that domestic R&D is a key driver of domestic innovation.

The discussion and data analysis is focused specifically on the computer and office equipment industry, as by defined by SIC 357 (1987 revision). SIC 357 is comprised of: computers (357l), storage devices (3572), terminals (3573), peripherals (3574), calculating machines (3578), and office machinery not elsewhere classified (3579). An important distinction is that this classification does not include software. Table below composition of SIC 357 (selected years, fraction of value of shipments)

	Electronic Computers	Computer Storage Devices	Computer Terminals	Computer Peripherals n.e.c.	Calculating and Accounting Machines	Office Machines n.e.c.
year	3571	3572	3575	3577	3578	3579
1972	0.451	0.086	0.041	0.187	0.078	0.158
1987	0.555	0.105	0.030	0.231	0.025	0.054
1996	0.575	0.121	0.009	0.239	0.018	0.037

Computers have comprised the largest share of the industry over the entire period, accounting for 45% in 1972 and nearly 60% by 1996. Peripherals make up the next largest group, accounting for 19% in 1972 and 24% in 1996. Computer storage devices accounted for 9% in 1972 and 12% by 1996. Terminals and calculators have been a small and decreasing portion of the industry over the entire period.

EMPIRICAL ANALYSIS

Results of OLS estimation

As explained earlier, in order to probe the complex relationship between R&D, international trade, and domestic innovation, ordinary least squares (OLS) with robust standard errors is used to estimate equation using industry level data on U.S. imports and exports, domestic R&D, and foreign R&D in the computer equipment industry.

The relationship between imports and domestic TFP is more ambiguous when we account for the interaction between imports and foreign R&D stock. In column 4, the coefficient on imports*)* remains positive, but the coefficient on the interactive term is negative. If we evaluate at the mean of foreign R&D stock, we can calculate the net effect of imports: a 1 percentage point increase in imports to sales is associated with a 1.15% increase in domestic TFP. However, if we evaluate at the maximum of foreign R&D stock, the net effect of imports is negative: a 1 percentage point increase in imports to sales is associated with a 1.26% decrease in domestic TFP.

These results suggest that as imports are more technically sophisticated, there is a negative impact on domestic innovation. This might reflect greater competition for the high end of the market, where goods are less commoditized and productivity gains are harder to achieve. Less technically sophisticated imports might affect domestic innovation differently. Import competition in the more commoditized segments of the industry might stimulate domestic manufacturers to seek more efficient methods of production. Import competition on the commoditized end might also spur domestic manufacturers to introduce new and better products.

Another potential concern is omitted variable bias that arises from idiosyncratic factors which affect TFP and are correlated with R&D and international trade, such as shocks that affect the whole economy in a given year.

A final caveat is that this is a small sample size, limited by the number of years of data available. Ideally, one might want to pool data for all four industries and use industry dummy variables. However, given considerable industry differences in the nature of innovation and the role of R&D, including intercept dummies for the industries does not allow for a fundamentally different relationship between R&D stock and TFP by industry.

Summary

The relationship between international trade and domestic TFP in this industry depends upon the level of foreign R&D stock. Exports can enhance domestic TFP as the level of foreign R&D stock increases, whereas imports discourage domestic innovation as the level of foreign R&D stock increases.

Some key quantitative results are:

- After we account for the effects of foreign R&D and international trade in the full specification, for every 1% increase in domestic R&D stock, there is a 1.07 % increase in domestic TFP.

- When we evaluate at the mean values of exports to sales and imports to sales, we find that a 1% increase in foreign R&D stock is associated with a 1.75% decrease in domestic TFP.
- Overall, exports contribute positively to domestic innovation. The positive effect is a function of increasing foreign R&D stock. Evaluated at the mean of foreign R&D stock, a 1% increase in exports to sales is associated with a 2.14% increase in domestic TFP.
- As the level of foreign R&D stock increases, imports have a negative impact on domestic innovation. When we evaluate at the mean of foreign R&D stock, a 1% increase in imports to sales is associated with a 1.15% increase in domestic TFP. However, a 1 percentage point increase in imports to sales is associated with a 1.26% decrease in domestic TFP at the maximum of foreign R&D stock.

INDUSTRY CHARACTERISTICS

The results in previous section raise important questions about the role of foreign R&D and international trade in the U.S. computer equipment industry. The results above suggest that increasingly sophisticated foreign markets might aid domestic innovation through exports, but at the same time, the greater technical sophistication of imports might hurt domestic innovation in this industry. In the following section, we will consider these findings in the context of the industry experience over this time period.

From the beginnings of the computer industry changes in market structure evolved concomitantly with technological advance (Bresnahan, 1999; Bresnahan and Malerba, 1999). This volatility has largely been driven by technological advance creating new market segments, e.g. microcomputers, then PCs. Competition in the computer industry is rooted in technological advance. Ongoing technological displacement of older models and even classes of computers occurs with the introduction of "better" computers, generally more powerful, cheaper and smaller in size.

The rapid technological progress in the computer industry derives from the extensive investment in R&D that characterizes this industry, and the remarkable characteristics of microelectronics technology through which its productivity was driven at a phenomenal rate. A combination of government, academic and private sector resources in confluence resulted in a formidable advantage for the development of the U.S. computer industry. The early years of the commercially viable computer industry are almost entirely an American story. Initial high risk purchase of high speed computers by the U.S. government contributed heavily to the first computers and continued for several decades (Flamm, 1988; M. I. T. Commission on Industrial Productivity, 1989b).

In many respects, the computer industry has had international aspects from the start. The computer industry began showing a trade deficit for the first time in 1991, the magnitude of which increased in the next years. However, the deficit to some extent reflects the shifting nature of the forefront of this industry. Several sectors remained domestic strengths while others saw a growth in imports. Peripherals, in particular, became increasingly dominated by imports. As well, the growth in imports in these sectors partly reflects shifts in production, particularly in the sourcing of components to lower-cost off-shore suppliers, and shifts in the sources of value added to software, as hardware increasingly became commoditized.

CONCLUSION

Taken together, the empirical results and the development of the computer equipment industry suggest a story in which sophisticated foreign competition has had both stimulating effects and deleterious effects on domestic innovation. The U.S. industry has been a strong global industry for the entire period. Investment in R&D has been an important component of innovation in the U.S. computer equipment industry, as is borne out by the empirical results and in consideration of the industry development.

At the same time, international connections were also an important part of the industry development. From the start, the computer equipment industry involved international distribution, and early advances in technology were developed in the U.K. and Germany as well as in the U.S. While U.S. based firms attained significant market share domestically and abroad in the 1970s and 1980s, increasing competition from producers in Japan and in Europe was always a factor. The negative relationship we see between foreign R&D stock and domestic TFP in the computer equipment industry supports the hypothesis that foreign R&D might discourage domestic innovation as producers abroad become more technically sophisticated. At the same time, the competition from increasingly sophisticated producers abroad also seemed to spur domestic innovation.

The relationship between increasing R&D abroad and domestic innovation is nuanced, particularly when we realize that the role of international trade and foreign R&D is highly intertwined. We saw in the empirical results that in the computer equipment industry, exports contribute positively to domestic TFP as the level of foreign R&D increases. This might reflect the existence of more ideas in a global setting, when foreign R&D is higher, there is more to learn through trade. As well, as foreign R&D increases, exporting provides contact with a technically sophisticated market including knowledgeable consumers and suppliers. Thus, the effect of exporting reflects the possibility of knowledge transmission, as well as the potentially stimulating effect of needing to compete in a highly innovative global market.

REFERENCES

Bernard, Andrew B. and Jensen, J. Bradford. "Exceptional Exporter Performance: Cause, Effect or Both?" *Journal of International Economics, 1999,4 7,* pp. *1-25.*

Branscomb, Lewis M. and Florida, Richard. "Challenges to Technology Policy in a Changing World Economy," L. M. Branscomb and J. H. Keller, Investing in Innovation: Creating a Research and Innovation Policy That Works. Cambridge, MA: The MIT Press, 1998,3-39.

Branstetter, Lee. "Are Knowledge Spillovers International or Intranational in Scope?" NBER Working Paper, 1996,5800.

Bresnahan, Timothy. "Computing," D. C. Mowery, *US.* Industry in 2000: Studies in Competitive Performance. Washington, D.C.: National Academy Press, 1999, 2 15-44.

Bresnahan, Timothy and Malerba, Franco eds. Industrial Dynamics and the Evolution of Firms' and Nations' Competitive Capabilities in the World Computer Industry. Cambridge, UK: Cambridge University Press, 1999.

Flamm, Kenneth. Creating the Computer: Government, Industry, and High Technology. Washington, D.C.: The Brookings Institution, 1988.

Grossman, Gene M. and Helpman, Elhanan. Innovation and Growth in the Global Economy. Cambridge, Massachusetts and London, England: The MIT Press, 1991a.

Lawrence, Robert Z. "Does a Kick in the Pants Get You Going or Does It Just Hurt? The Impact of International Competition on Technological Change in US Manufacturing," R. E. Feenstra The Impact of International Trade on Wages. Chicago: University of Chicago Press, 2000, 197-224.

Mowery, David C. and Rosenberg, Nathan. Technology and the Pursuit of Economic Growth. Cambridge: Cambridge University Press, 1989.