ABSTRACT

Modeling Technology Diffusion within Vietnam: A Network Approach

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This paper attempts to model three types of technology transfer using survey data from small and medium enterprises in Vietnam. Knowledge is assumed to enter the country through exporting firms and then spreads by one of three mechanisms: geographic diffusion, industry-specific diffusion, or some combination. To model these processes, a separate network structure is designed for each mechanism in which the firm's centrality is determined and combined with the firm's export status to form a measure of the firm's influence in the network. This influence is then used as an input into the firm's production function. I find that a one-percent increase in a firm's centrality can provide a large increase in productivity. In a geographic model diffusing non-industry specific knowledge, increasing a firm's closeness to exporting firms by one percent could increase productivity by up to thirty-nine percent.

Modeling Technology Diffusion within Vietnam: A Network Approach

by

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CHAPTER ONE

Introduction

Productivity differences have been shown to be the main determinant of variation in incomes across countries (Easterly and Levine 2001). In order to minimize these differences, less-developed countries must increase their productivity by performing research and development. For many countries, however, this is not profitable, and in some cases, not even possible due to lack of resources such as advanced infrastructure and a highly-educated workforce. The most efficient path for less developed countries is to encourage the diffusion of technology created in developed countries. This allows countries to increase their productivity and raise their incomes, while not having to suffer the costs of performing their own research.

There are a number of ways that knowledge created in developed countries can be transferred to less-developed countries, including international trade, foreign direct investment, international labor migration, foreign aid, remittances, etc. However, not much is known about how this information travels once it reaches the developing country. This paper focuses on the diffusion of knowledge acquired by firms in developing countries that export to developed countries. Several papers have suggested that this is a probable mechanism for knowledge transfer, as the importing firm hopes to receive a higher quality product, pay a lower price, or both. Pack and Saggi create a model of vertical technological spillover that demonstrates this relationship (2001). Their paper concludes that it is in the best interest of both firms for this transfer to occur. Even if this knowledge spills over to other firms in the developing country, the two original firms are still shown to benefit. How this knowledge leaks across the developing country, however, is outside the scope of their paper.

The goal of this paper is to model three different types of technology transfer within Vietnam: geography-based diffusion, industry-based diffusion and a combination of the two. These are examined by constructing networks of small and medium enterprises, with a different network structure for each diffusion mechanism. In each network, the connections between firms take on different values depending on the type of diffusion being examined. A firm's position in the network is observed and considered an input in the firm's production function. A procedure created by Olley and Pakes is used to determine if the firm's position plays a significant role in determining productivity.

The size of this effect on productivity is most likely a function of the export destination. In other words, exporting to a low-productivity country should not provide as large of a spillover as exporting to a high-productivity country. High productivity is the result of innovation and almost all of the world's research occurs in a relatively small number of countries. Over half of the world's spending on research and development occurs in the United States, China and Japan alone. If research is a primary driver of technological innovation, this must be taken into account when choosing what countries to interact with. Some papers, for example, find that exporting to China does not necessarily enhance output growth of countries in Africa, but exporting to OECD countries has a strong positive effect on growth (Baliamoune-Lutz 2011). This has been shown to be the case with foreign direct investment as well, as one paper shows that Chinese firms that receive investment from OECD countries significantly outperform those with investment from Hong Kong, Taiwan and Macao (Kamal 2014). OECD-supported firms experienced relatively higher profits, wages, and capital intensities. These studies imply that any participation in any international markets may not be sufficient for large productivity gains to occur. Countries should try to interact with the most advanced countries as possible.

To examine this theory, four different models are specified for each network structure with each representing a different export destination: the United States, Japan, China and the Association of Southeast Asian Nations (ASEAN). The resulting coefficients can then be compared across the same network structure to determine which export destinations will provide the largest gains to productivity.

This paper adds to the current literature on productivity by constructing a network to view the effects of connections to firms. To the author's knowledge, this is one of the first papers that do so. The vast majority of the literature attempting to observe the effects of other firms simply include the number of firms in the area into the regression. This methodology cannot capture the patterns of interactions that can be observed using network analysis. With new types of data becoming available, network analysis should begin to play a larger role in how we study the relationships between firms.

The remainder of the paper is organized as follows. In the next chapter, the data is described and summary statistics are provided. Chapter Three describes how the networks are constructed, Chapter Four analyzes a firm's influence in the network and provides a simple test of the methodology used. Chapter Five presents the estimation procedure used to calculate a firm's productivity, Chapter Six presents the empirical findings and Chapter Seven concludes.

CHAPTER TWO

Data

This paper uses data from three surveys conducted by the Central Institute for Economic Management of the Ministry of Planning and Investment of Vietnam, the Institute of Labour Science and Social Affairs of the Ministry of Labour, Invalids and Social Affairs of Vietnam, and the Development Economics Research Group of the University of Copenhagen. Multiple surveys have been performed but this paper uses the surveys from 2005, 2007 and 2009. Each survey covers roughly 2,500 small and medium enterprises and contains a small number of repeat observations. Due to limitations, the surveys only cover 10 provinces: Ha Noi, Ha Tay, Hai Phong, Ho Chi Minh City, Khanh Hoa, Lam Dong, Long An, Nghe An, Phu Tho and Quang Nam. Figure A.1 maps the location of the districts that the firms operate in.

Due to the structure of the survey questions, annual economic account data is available for 2003 through 2008. After matching the firm's identification number and opening date across surveys, there are a total of 5,054 observations. Investment is then calculated, assuming a depreciation rate of 10%. Observations from the years 2003, 2005 and 2007 are removed, as the number of firms is unknown. It is assumed that each firm in the districts is given a survey in 2004, 2006 and 2008 so the number of responses reflects the number of districts. Firms may have been open in 2003 and closed in 2004, which would alter the network structure. Removing observations in these years is the simplest way to account for that possibility. There are also a number of observations which show firms have no employees, no capital stock, etc. These are removed, as well as any firms that have a negative amount of investment. Positive investment is a requirement of the estimation procedure used to determine a firm's productivity. Removing this subset leaves 1,397 observations of 1,061 firms. Table 2.1 presents some basic summary statistics of the firms used in the analysis.

Table 2.1 Descriptive Statistics - Firms

Year	Age	Log Output	Log Capital	Log Labor	Log Materials
2004	9.04	7.05	6.98	2.21	6.39
2006	10.81	7.25	7.35	2.27	6.53
2008	9.37	7.93	7.66	2.61	7.35

CHAPTER THREE

Network Construction

The first step in creating a network is deciding the definitions of nodes and edges. As firms are the units being analyzed, each node corresponds to an individual firm that is surveyed. Edges are the connections that carry the information between nodes. These connections can be weighted or un-weighted. As the weight increases, the strength of the connection between two nodes increases and one node’s position depends more and more on the position of the other node. Edges can also be directed or undirected. If an edge is directed, this means that information originates at Firm I and is sent to Firm J, and Firm J may or may not send anything back. Because we are using geography and industry as proxies of distance, each network will be undirected. In other words, the strength of the connection from Firm I to Firm J will be the same as Firm J to Firm I.

To construct the networks, an adjacency matrix, A, is constructed for each year for each model. An adjacency matrix is a square matrix which contains the strengths of the connections between each pair of firms. Say there are n firms in a given year. The size of the adjacency matrix will be n x n, where $A_{i,j}$ represents the weight of the connection from Firm I to Firm J. Because they are symmetric, $A_{i,j}$ will equal $A_{j,i}$. Every entry will follow $0 \leq A_{i,j} \leq 1$. The one exception to this rule is the diagonal of the matrix, which represents a firm’s connection to itself. This type of connection is not used as part of the analysis as firms are not allowed to be connected to themselves.

If this diffusion is solely based on geography, than firms that are closer to exporters should have a higher productivity than those that are further away. This model uses knowledge that is not industry-specific, so each firm is connected to every other firm in the country. This allows exporters from any industry to improve the productivity of every other firm of any industry. In other words, a textile firm should be able to acquire information from a construction firm and benefit. To construct the adjacency matrix for this network, all firms will be connected to all other firms, as all firms are connected by geography. If two firms operate in the same district, their connection has a strength of 1. Otherwise, the strength of these connections will be the inverse of the distance between the respective districts that the firms are located in. The further apart the districts are, the weaker the connection between firms and the smaller the spillover. Figure 3.1 shows a simple illustration of how this network is constructed. In the figure, Firms 1, 2 and 3 are all located in District 1. This would result in strong connections between these firms and is represented by the bolder lines. Firms 4, 5 and 6 are all located in District 2 and have strong connections to each other. All firms in District 1 are connected to all firms in District 2, but there is a weaker connection between them, represented by the thinner lines.

The second network structure attempts to model the diffusion of industry specific knowledge. This information is of no benefit to firms that are in a different industry. This type of knowledge could include how to package a certain product better, how to operate a particular machine more efficiently, etc. For example, a construction firm could learn how to operate a machine better, but it is unlikely that this could spill over to a textile firm. In contrast to the first model, geography does not play a role here. To model this

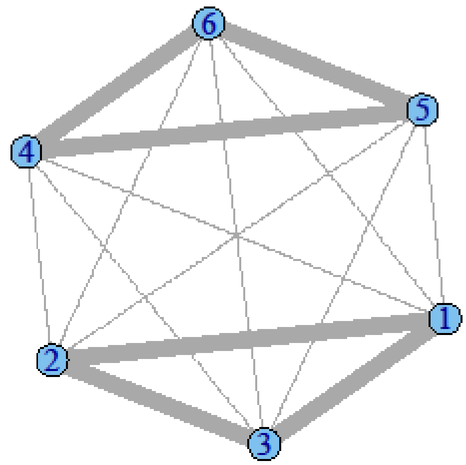

Figure 3.1 Geographic Network Representation

process, a firm is only connected to firms that are in the same industry. Each connection will have a weight of 1. This implies that a firm that is 10 kilometers away from an exporter will receive the same benefit as a firm 1,000 kilometers away, but only if they are in the same industry. Figure 3.2 shows an example of what this network structure would look like. Firms 1, 2 and 3 produce very similar products and are connected to each other. Each firm could be in a different province or the same district, it does not change the connections. Firms 4, 5 and 6 are also of the same industry and have connections similar to the other firms. However, there are no connections that exist between the different industries.

The third and final type of diffusion is a combination of the previous two accounting for both, geography and industry. The knowledge is industry-specific as in the second model, but decays with geography like the first model. To construct the adjacency matrix for this network, each firm will only be connected to firms that are in the same industry. The weight of these connections is equal to the inverse of the distance in

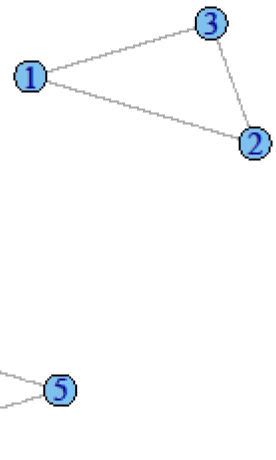

Figure 3.2 Sectoral Network Representation

kilometers between the districts that the firms are located in. Figure 3.3 provides an example of tis network structure. In this figure, Firms 1, 2 and 3 are of the same industry. However, because Firms 1 and 2 are in the same district, they share a stronger connection that Firms 1 and 3 or Firms 2 and 3. Firms 4, 5 and 6 are of a different industry, with Firms 5 and 6 operating in the same district. Notice there are still no connections across industries, even though geography now plays a role.

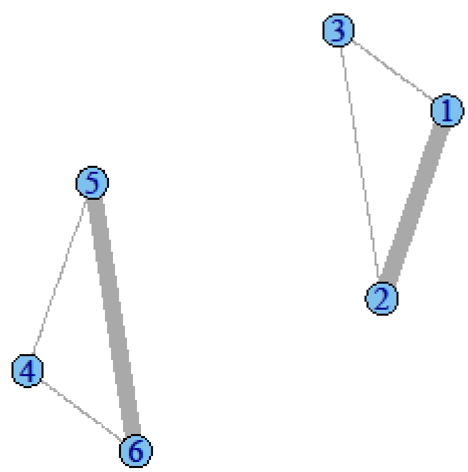

Figure 3.3 Combined Network Representation

CHAPTER FOUR

Network Analysis

The standard measure of a node's influence in a network is its eigenvector centrality. This is a recursive measure that is determined by the influences of the nodes that a node is connected to. A firm's centrality, then, is the sum of the centralities of all firms that a firm is connected to, weighted by the strengths of the connections. This function can be written recursively as:

$$x_i = \frac{1}{\lambda} * \sum_{j=1}^{n} A_{i,j} x_j, \quad j \neq i \tag{4.1}$$

where x_i is the eigenvector centrality of Firm I, $A_{i,j}$ is entry (i,j) in the adjacency matrix, λ is a constant and x_j is the eigenvector centrality of Firm J. This equation can be rewritten in matrix form as

$$\lambda * x = A * \mathrm{x} \tag{4.2}$$

which makes it clear that x is the eigenvector of the adjacency matrix with an eigenvalue of λ. When a firm is connected to firms that have a high centrality, its own centrality increases. A higher eigenvector centrality implies that a firm is very well connected to other firms with a high centrality. If a firm has a higher centrality, it follows that the firm will have more interaction with other firms and will receive more information than firms with a lower centrality. Firms with the higher centrality should then have a higher productivity.

The goal of this paper is to observe how knowledge spreads from exporting firms and this measure does not differentiate between firms that export and those that do not. A measure is needed that allows exporting to affect a firm's centrality. Ideally, firms that export would have a higher centrality by construction, which would increase the centrality of firms that are closely connected to them. There exists such a measure called alpha centrality (Bonacich and Lloyd 2001). This measure allows a firm's influence to depend on its eigenvector centrality, but also its exporting status. The parameter alpha is inserted to determine the relative importance of centrality versus export status. This measure can be written in matrix form as

$$x = (I - \alpha * A^T)^{-1} * e \tag{4.3}$$

where I is an identity matrix, A is the adjacency matrix and e is a vector containing firms' export statuses. This function can also be written recursively as

$$x_i = e_i + \alpha * \sum_{j=1}^{n} A_{i,j} x_j, \quad j \neq i \tag{4.4}$$

where e_i is Firm I's export status (1 if Firm I exports to the particular destination, 0 otherwise), $A_{i,j}$ is entry (i,j) of the adjacency matrix and x_j is the alpha centrality of Firm J. The levels of alpha that are significant will show the relative importance of a firm's export status compared to its connections to firms that export. This measure has a number of important features. It allows a level of alpha to be determined by the econometrician so the importance of a firm's network can be compared to exporting. Also, it allows a firm connected to relatively few exporting firms to have a higher centrality than a firm connected to a larger number of non-exporting firms, which is an important characteristic. Fewer exporters should have a larger effect on productivity than being connected to many non-exporting firms as the exporting firms directly contact the developed countries and import the technology.

To confirm the model is performing as it should, a simple test is performed. In the survey conducted in 2009, firm managers are asked if they are aware of the Agency for Small and Medium Enterprise Development, or ASMED. This is a government agency that helps coordinate policies to support SMEs. It has a website assembled which includes information on the appropriate licenses and permits required to operate a business, how to acquire financing, information for submitting tax forms, as well as contact information for other SME support institutions. It is likely that if someone knows about this program, they are likely to tell others about it, such as neighbors, friends and family members. If the networks constructed earlier work as they should, then firms with a higher centrality should have a higher probability of knowing about this program. This hypothesis can be tested by running a probit and including a firm’s centrality as a dependent variable. The firm’s centrality is calculated using the first model, accounting for geography only. It does not make sense to account for industry as this knowledge could be used by construction firms as easily as textile firms. A number of covariates are also included in the probit. These other variables, such as number of employees, may affect the probability as firms with more employees have an increased probability of knowing about the program, regardless of the firm’s centrality. If the network and centrality measurement function correctly, than the eigenvector centrality measure should have a positive and significant coefficient in determining a firm’s awareness of the program. Table 4.1 reports the result of this probit.

Table 4.1 Effect of Centrality on Program Awareness

Aware of Program	Model A	Model B	Model C
Centrality	0.82**	0.77*	0.74*
	(2.71)	(2.43)	(2.27)
Number of Employees		0.0082***	0.0080***
		(7.60)	(7.41)
Age			−0.019**
			(−3.02)

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A positive and significant coefficient on the centrality measure confirms that firms that are more central have a higher probability. This is important because it confirms that knowledge flows from firm to firm and that the centrality measure can detect it. It also shows that firms with a higher centrality are more likely to know information, confirming the theory that firms that are more central, are more likely to have been exposed to more information. As a result, this higher centrality should result in a higher productivity. It might have been more efficient to introduce the AMSED program to firms that are shown to be more central, as this may have possibly increased the number of firms that heard about the program. However, this paper cannot prove that theory. Other papers have shown, however, that injection points in a network can play a crucial role in determining the awareness of a program (Banerjee, Chandrasekhar, Duflo, and Jackson 2012).

CHAPTER FIVE

Estimating Firm Productivity

The next step is to estimate the effect of alpha centrality on a firm's productivity by inserting it in the firm's production function. Consider the following:

$$yit = \beta 0 + \beta a * ait + \beta l * lit + \beta m * mit + \beta k * kit + \beta x * xit + wit + nit \qquad (5.1)$$

where y_{it} is the log of output, a_{it} is the age of the firm, l_{it} is the log of the number of employees, m_{it} is the log of raw materials used, k_{it} is the log of capital, x_{it} is alpha centrality, w_{it} is productivity, and n_{it} is measurement error or a shock to productivity. Subscripts i and t represent firm and time, respectively. These parameters cannot be estimated using ordinary least squares for a number of reasons.

First, there is simultaneity bias (Griliches and Mairesse 1995). The levels of capital and labor employed are not exogenous but are chosen by the firm's manager based on the optimization of some unknown function. This function involves a prior belief of the firm's productivity which cannot be observed by the econometrician. This belief violates an assumption of OLS, as the residual, or productivity, is correlated with one or more independent variables. This will result in biased coefficients of the capital and labor variables. There also exists selection bias. This problem arises from the relationship between a firm's productivity and its decision to remain open or to exit the market. In some cases, a balanced panel is used to correct for this problem. However, balancing this panel of firms would result in the loss of a large amount of data.

There exists, however, a semiparametric estimation procedure that accounts for the effects of these two sources of bias (Olley and Pakes 1996). The major innovation of this method is to think of a firm's productivity, w_{it}, as a state variable that plays a role in a firm's decision on the levels of inputs, as well as its decision to remain open or exit the market. This assumption allows investment to be modeled as $i_{it} = i_{it}(w_{it},a_{it},k_{it})$, which can then be inverted to show that $w_{it} = h_{it}(i_{it},a_{it},k_{it})$. For this transformation to be possible, investment must be greater than 0, removing a small subset of firms from the analysis. Substituting this into equation 5.1 results

in

$$yit = \beta l * lit + \beta m * mit + \beta x * xit + \varphi(iit,ait,kit) + nit, \tag{5.2}$$

where

$$\varphi it(iit,ait,kit) = \beta 0 + \beta a * ait + \beta k * kit + hit(iit,ait,kit). \tag{5.3}$$

The function, φ is a second-order polynomial series in investment, age and capital. Equation 5.2 can be estimated with ordinary least squares and will give accurate estimates of β_l, β_m and β_x as the polynomial is a control for unobserved productivity. The remaining parameters, β_a and β_k, are not only dependent on current productivity, but the distribution of past productivities also.

To determine the effects of age and capital, their roles must be separated into effects on investment decisions and effects on productivity. To achieve this, the bias due to selection needs to be dealt with. A firm will exit the market if it is not profitable, meaning that its productivity is less than some threshold, based on its capital and age. A probit model is then used to estimate the probability of a firm exiting the market at time *t*.

Independent variables include investment, capital and age at time *t-1*, as well as the squares and cross-products of those variables. Let ρ_t represent this probability.

The third and final step of this procedure is to fit the following model with non-linear least squares:

$$y_{it} - \hat{\beta}_m * m_{it} - \hat{\beta}_l * l_{it} - \hat{\beta}_x * x_{it} = \beta_a * a_{it} + \beta_k * k_{it} + g(\hat{\phi}_{t-1} - \beta_k * k_{i,t-1} - \beta_a * a_{i,t-1}, \hat{\rho}_t) + \epsilon_{it} + n_{it} \tag{5.5}$$

where g() is approximated by a second-order polynomial, and $_t$ is innovation in year *t*. As this process consists of three steps, standard errors are constructed using a bootstrapping technique, using 100 repetitions where all observations for a single firm are clustered.

CHAPTER SIX

Results and Discussion

The results of the geographic diffusion model are shown in Tables A.2 - A.5. Each table shows a different export destination, with levels of alpha ranging from 0.1 to 1.0. Levels of alpha greater than 1 are not tested as it is unlikely that a firms connections will play a larger role in determining productivity than exporting. When the export destination is the United States, Japan or ASEAN, high significance is found when alpha is equal to 0.1. This can be interpreted as a firm's connections to exporters is roughly ten percent as important as exporting directly to one of these destinations. The coefficients when alpha equals 0.1 are all positive so a high proximity to exporters does have a positive effect on a firm's productivity. A one percent increase in alpha centrality with respect to the United States will result in a twenty-five percent increase in that firm's productivity, with the Japan and ASEAN models showing results of thirty-nine and twenty-eight percent, respectively. With respect to China, no significance is found, meaning that firms which export to China do not play a large role in changing the productivity of the surrounding firms.

Tables A.6 - A.9 show the results of the diffusion model of industry-specific knowledge. There is very little significance found when alpha is equal to 0.1 and no significance at other levels. The lack of significance implies that geography must play an important role in the diffusion process. This model gave the same spillover to all firms in the country in a particular sector, regardless of how the far the distance between two firms. The spillover must decay as it travels away from an exporting firm. One interpretation of this is as the distance between two firms increases, the probability that they communicate directly decreases. The second interpretation is that firms must not pass on one-hundred percent of the knowledge they receive. If they did, then geography would not play a role as knowledge would work its way through the network and all firms would receive the same amount of information.

Tables A.10 - A.13 show the results of the third model, geographic diffusion of industry-specific knowledge. The effect of alpha centrality, with respect to exporting to the U.S., is positive and significant at almost all levels of alpha. The effect of a one percent increase in centrality ranges from a thirty-two to thirty-eight percent increase in productivity. This range peaks at a forty-seven percent increase for the Japan model when alpha is equal to 0.3. Being close to firms that export to ASEAN or China, however, does not have a significant effect on a firm's productivity using this network structure.

China shows no significance for any level of alpha in any of the three models. In addition, when a dummy variable of exporting to China is inserted into equation 5.1 in place of alpha centrality, it shows no significance. If this estimate is true, then Vietnamese firms are not gaining anything by exporting to China. This agrees with the results found in Baliamoune-Lutz (2011). The most obvious reason for this is that Chinese firms are not more productive than Vietnamese firms and as a result, they have no original knowledge to share. If the exporting firm does not acquire knowledge that makes it more productive, it follows that the firm could not share knowledge to make other Vietnamese firms more productive either.

CHAPTER SEVEN

Conclusion

In this paper, I constructed three varying network structures to represent three different models of technology diffusion. A firm's position in a network is then considered an input into its production function. Overall, the results presented show that the connections a firm has can have a significant effect on productivity. The more connected a firm is, the more information that it receives and the more productive it becomes. The magnitude of this effect, however, depends on the origin country of the knowledge. If an exporting firm does not receive knowledge that will make it more productive, then it cannot increase the productivity of its connections or of itself.

For future research, I hope to explore more sophisticated ways of constructing and analyzing networks of firms. As an example, a network created using transaction data could play a much larger role in explaining how technology is transferred. This would only allow firms to be connected if one firm purchased intermediate inputs from another firm, resulting in a directed weighted network. The weight would be the amount of products purchased. The more goods a firm buy from another, the stronger the connection between the two firms. This network would be based on actual relationships and not just probabilities of communication, like geography. A better understanding of these network effects will go a long way in supporting small and medium enterprises.

APPENDIX

APPENDIX A

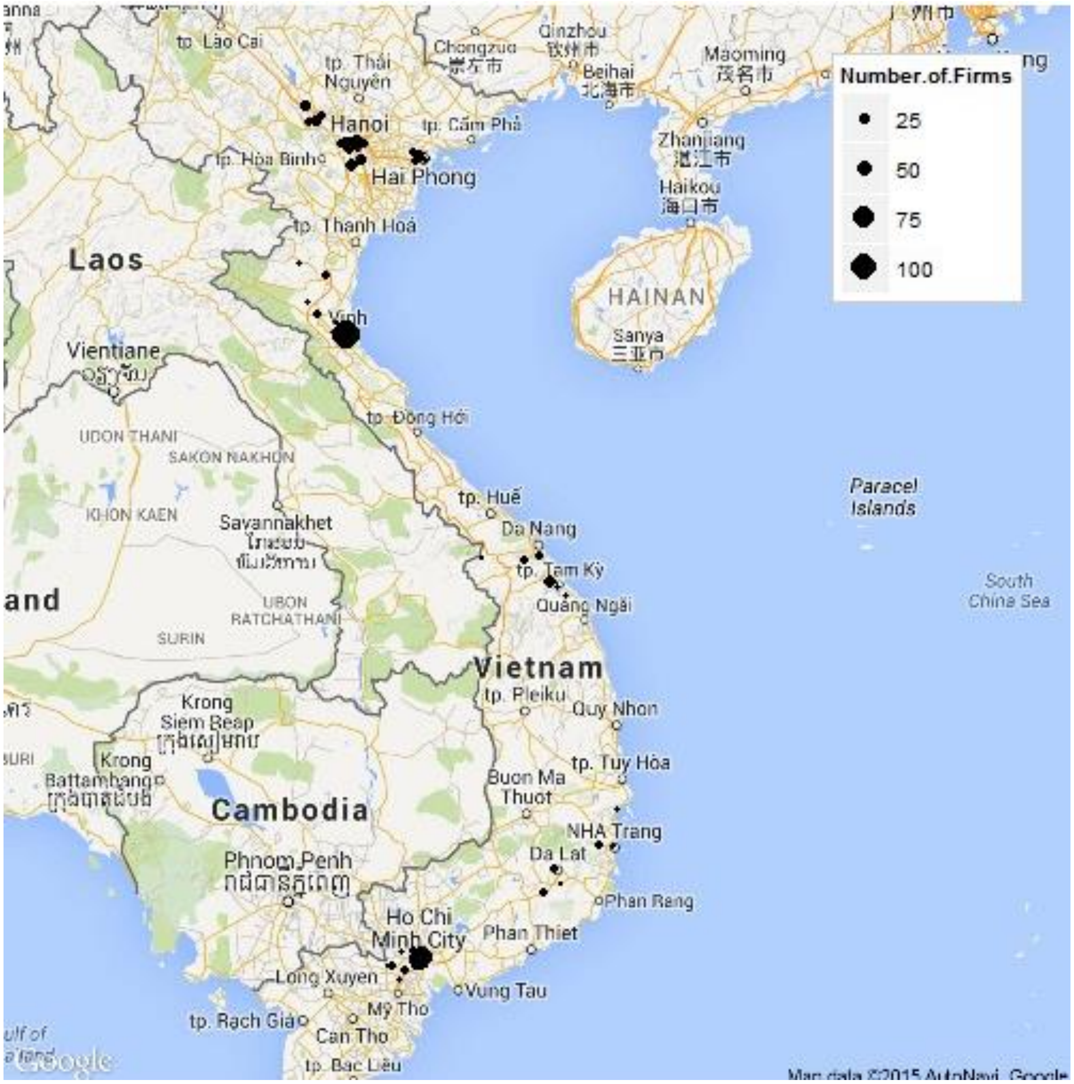

Figure A.1 Locations of Small and Medium Enterprises

Table A.2 Geographic Spillover of Knowledge, Exporting to United States

Log Output	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
Age	−0.0079	−0.0080	−0.0082	−0.0084	−0.0085	−0.0087	−0.0088	−0.0087	−0.0084	−0.0082
	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)
Log Capital	0.053*	0.056**	0.056**	0.055**	0.055**	0.054**	0.054*	0.054*	0.054*	0.054*
	(2.54)	(2.78)	(2.76)	(2.67)	(2.62)	(2.61)	(2.58)	(2.54)	(2.50)	(2.51)
Log Labor	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***
	(11.84)	(12.02)	(12.06)	(12.07)	(12.07)	(12.07)	(12.07)	(12.07)	(12.07)	(12.07)
Log Materials	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***
	(29.57)	(29.58)	(29.61)	(29.63)	(29.64)	(29.64)	(29.64)	(29.64)	(29.64)	(29.64)
$\alpha = 0.1$	0.25***									
	(3.39)									
$\alpha = 0.2$		0.13								
		(1.37)								
$\alpha = 0.3$			0.017							
			(0.17)							
$\alpha = 0.4$				−0.048						
				(−0.51)						
$\alpha = 0.5$					−0.083					
					(−0.90)					
$\alpha = 0.6$						−0.10				
						(−1.09)				
$\alpha = 0.7$							−0.11			
							(−1.17)			
$\alpha = 0.8$								−0.12		
								(−1.22)		
$\alpha = 0.9$									−0.12	
									(−1.27)	
$\alpha = 1.0$										−0.13
										(−1.35)

Table A.3 Geographic Spillover of Knowledge, Exporting to Japan

Log Output	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
Age	−0.0080	−0.0083	−0.0084	−0.0084	−0.0083	−0.0081	−0.0082	−0.0082	−0.0081	−0.0083
	(−0.01)	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.01)	(−0.01)	(−0.02)	(−0.02)	(−0.02)
Log Capital	0.055*	0.054*	0.053*	0.053*	0.053*	0.053*	0.054*	0.054*	0.054*	0.054*
	(2.49)	(2.45)	(2.44)	(2.42)	(2.42)	(2.48)	(2.50)	(2.46)	(2.50)	(2.54)
Log Labor	0.32***	0.32***	0.33***	0.33***	0.33***	0.32***	0.32***	0.32***	0.32***	0.32***
	(11.85)	(12.00)	(12.08)	(12.11)	(12.12)	(12.12)	(12.10)	(12.09)	(12.08)	(12.08)
Log Materials	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***
	(29.74)	(29.61)	(29.57)	(29.56)	(29.57)	(29.60)	(29.63)	(29.65)	(29.65)	(29.65)
$\alpha = 0.1$	0.39**									
	(2.89)									
$\alpha = 0.2$		0.24								
		(1.94)								
$\alpha = 0.3$			0.24							
			(1.66)							
$\alpha = 0.4$				0.25						
				(1.42)						
$\alpha = 0.5$					0.25					
					(1.24)					
$\alpha = 0.6$						0.088				
						(0.56)				
$\alpha = 0.7$							−0.091			
							(−1.10)			
$\alpha = 0.8$								−0.13		
								(−1.75)		
$\alpha = 0.9$									−0.15*	
									(−2.24)	
$\alpha = 1.0$										−0.15*
										(−2.12)

Table A.4 Geographic Spillover of Knowledge, Exporting to ASEAN

Log Output	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
Age	−0.0084	−0.0083	−0.0081	−0.0081	−0.0083	−0.0085	−0.0084	−0.0083	−0.0083	−0.0083
	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)
Log Capital	0.055*	0.054**	0.054**	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*
	(2.54)	(2.59)	(2.59)	(2.51)	(2.44)	(2.47)	(2.46)	(2.44)	(2.48)	(2.47)
Log Labor	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***
	(12.04)	(12.09)	(12.08)	(12.06)	(12.05)	(12.05)	(12.05)	(12.05)	(12.06)	(12.08)
Log Materials	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***
	(29.43)	(29.55)	(29.57)	(29.61)	(29.61)	(29.62)	(29.62)	(29.63)	(29.64)	(29.66)
$\alpha = 0.1$	0.28***									
	(3.33)									
$\alpha = 0.2$		0.19*								
		(2.57)								
$\alpha = 0.3$			0.17							
			(1.58)							
$\alpha = 0.4$				0.11						
				(1.00)						
$\alpha = 0.5$					−0.025					
					(−0.24)					
$\alpha = 0.6$						−0.051				
						(−0.48)				
$\alpha = 0.7$							−0.075			
							(−0.69)			
$\alpha = 0.8$								−0.11		
								(−1.01)		
$\alpha = 0.9$									−0.15	
									(−1.67)	
$\alpha = 1.0$										−0.19*
										(−2.21)

Table A.5 Geographic Spillover of Knowledge, Exporting to China

Log Output	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
Age	−0.0085	−0.0082	−0.0083	−0.0083	−0.0082	−0.0083	−0.0083	−0.0083	−0.0083	−0.0083
	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)
Log Capital	0.055**	0.054*	0.053*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*
	(2.67)	(2.53)	(2.51)	(2.53)	(2.53)	(2.52)	(2.51)	(2.50)	(2.47)	(2.47)
Log Labor	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***
	(12.01)	(12.07)	(12.08)	(12.10)	(12.11)	(12.11)	(12.11)	(12.10)	(12.09)	(12.09)
Log Materials	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***
	(29.51)	(29.59)	(29.60)	(29.59)	(29.61)	(29.62)	(29.63)	(29.65)	(29.66)	(29.66)
$\alpha = 0.1$	0.11									
	(0.88)									
$\alpha = 0.2$		−0.0068								
		(−0.07)								
$\alpha = 0.3$			−0.11							
			(−1.07)							
$\alpha = 0.4$				−0.18*						
				(−2.04)						
$\alpha = 0.5$					−0.15					
					(−1.33)					
$\alpha = 0.6$						−0.19				
						(−1.64)				
$\alpha = 0.7$							−0.23*			
							(−2.34)			
$\alpha = 0.8$								−0.21		
								(−1.71)		
$\alpha = 0.9$									−0.17	
									(−1.34)	
$\alpha = 1.0$										−0.16
										(−1.20)

Table A.6 Spillover of Industry-Specific Knowledge, Exporting to United States

Log Output	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
Age	−0.0078	−0.0083	−0.0084	−0.0084	−0.0084	−0.0084	−0.0083	−0.0083	−0.0083	−0.0083
	(−0.01)	(−0.02)	(−0.02)	(−0.02)	(−0.01)	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.02)
Log Capital	0.052*	0.053*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*
	(2.49)	(2.53)	(2.51)	(2.50)	(2.50)	(2.51)	(2.52)	(2.52)	(2.52)	(2.54)
Log Labor	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***
	(11.91)	(12.00)	(12.01)	(12.01)	(12.01)	(12.01)	(12.01)	(12.01)	(12.01)	(12.02)
Log Materials	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***
	(29.56)	(29.53)	(29.52)	(29.52)	(29.52)	(29.53)	(29.53)	(29.53)	(29.53)	(29.53)
$\alpha = 0.1$	0.21*									
	(2.11)									
$\alpha = 0.2$		0.18								
		(1.30)								
$\alpha = 0.3$			0.19							
			(1.17)							
$\alpha = 0.4$				0.21						
				(1.15)						
$\alpha = 0.5$					0.22					
					(1.14)					
$\alpha = 0.6$						0.23				
						(1.13)				
$\alpha = 0.7$							0.23			
							(1.12)			
$\alpha = 0.8$								0.23		
								(1.10)		
$\alpha = 0.9$									0.23	
									(1.09)	
$\alpha = 1.0$										0.24
										(1.07)

Table A.7 Spillover of Industry-Specific Knowledge, Exporting to Japan

Log Output	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
Age	−0.0077	−0.0083	−0.0084	−0.0084	−0.0084	−0.0084	−0.0083	−0.0083	−0.0083	−0.0083
	(−0.01)	(−0.02)	(−0.02)	(−0.02)	(−0.01)	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.02)
Log Capital	0.052*	0.053*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*
	(2.55)	(2.51)	(2.51)	(2.50)	(2.50)	(2.51)	(2.52)	(2.52)	(2.52)	(2.54)
Log Labor	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***
	(11.92)	(12.00)	(12.01)	(12.01)	(12.01)	(12.01)	(12.01)	(12.01)	(12.01)	(12.01)
Log Materials	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***
	(29.59)	(29.53)	(29.52)	(29.52)	(29.52)	(29.52)	(29.53)	(29.53)	(29.53)	(29.53)
$\alpha = 0.1$	0.28*									
	(2.26)									
$\alpha = 0.2$		0.20								
		(1.37)								
$\alpha = 0.3$			0.20							
			(1.18)							
$\alpha = 0.4$				0.21						
				(1.16)						
$\alpha = 0.5$					0.22					
					(1.15)					
$\alpha = 0.6$						0.23				
						(1.13)				
$\alpha = 0.7$							0.23			
							(1.12)			
$\alpha = 0.8$								0.23		
								(1.10)		
$\alpha = 0.9$									0.24	
									(1.09)	
$\alpha = 1.0$										0.24
										(1.07)

Table A.8 Spillover of Industry-Specific Knowledge, Exporting to ASEAN

Log Output	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
Age	−0.023	−0.0087	−0.0083	−0.0082	−0.0082	−0.0081	−0.0081	−0.0081	−0.0081	−0.0081
	(−0.03)	(−0.02)	(−0.01)	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.02)
Log Capital	0.045*	0.053*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*
	(2.08)	(2.42)	(2.44)	(2.45)	(2.45)	(2.48)	(2.49)	(2.50)	(2.47)	(2.49)
Log Labor	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***
	(12.06)	(12.05)	(12.04)	(12.04)	(12.03)	(12.03)	(12.02)	(12.02)	(12.02)	(12.02)
Log Materials	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***
	(29.42)	(29.50)	(29.53)	(29.54)	(29.55)	(29.55)	(29.56)	(29.56)	(29.56)	(29.56)
$\alpha = 0.1$	0.099									
	(1.28)									
$\alpha = 0.2$		0.15								
		(1.43)								
$\alpha = 0.3$			0.18							
			(1.49)							
$\alpha = 0.4$				0.19						
				(1.42)						
$\alpha = 0.5$					0.20					
					(1.34)					
$\alpha = 0.6$						0.20				
						(1.25)				
$\alpha = 0.7$							0.21			
							(1.18)			
$\alpha = 0.8$								0.21		
								(1.12)		
$\alpha = 0.9$									0.21	
									(1.06)	
$\alpha = 1.0$										0.21
										(1.01)

Table A.9 Spillover of Industry-Specific Knowledge, Exporting to China

Log Output	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
Age	−0.0080	−0.0082	−0.0083	−0.0083	−0.0083	−0.0083	−0.0083	−0.0083	−0.0083	−0.0083
	(−0.02)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)
Log Capital	0.055**	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*
	(2.65)	(2.53)	(2.49)	(2.50)	(2.50)	(2.51)	(2.52)	(2.52)	(2.53)	(2.53)
Log Labor	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***
	(11.94)	(12.03)	(12.04)	(12.03)	(12.03)	(12.03)	(12.03)	(12.03)	(12.03)	(12.03)
Log Materials	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***
	(29.57)	(29.54)	(29.56)	(29.56)	(29.57)	(29.58)	(29.59)	(29.59)	(29.60)	(29.60)
$\alpha = 0.1$	0.18*									
	(2.08)									
$\alpha = 0.2$		0.14								
		(1.22)								
$\alpha = 0.3$			0.11							
			(0.89)							
$\alpha = 0.4$				0.11						
				(0.77)						
$\alpha = 0.5$					0.11					
					(0.71)					
$\alpha = 0.6$						0.11				
						(0.68)				
$\alpha = 0.7$							0.11			
							(0.67)			
$\alpha = 0.8$								0.11		
								(0.66)		
$\alpha = 0.9$									0.11	
									(0.65)	
$\alpha = 1.0$										0.12
										(0.64)

Table A.10 Geographic Spillover of Industry-Specific Knowledge, Exporting to United States

Log Output	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
Age	−0.0080	−0.0076	−0.0074	−0.0074	−0.0075	−0.0075	−0.0076	−0.0077	−0.0078	−0.0078
	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.02)
Log Capital	0.053*	0.052*	0.053**	0.054**	0.055**	0.056**	0.056**	0.056**	0.056**	0.056**
	(2.53)	(2.52)	(2.60)	(2.66)	(2.69)	(2.77)	(2.76)	(2.78)	(2.77)	(2.74)
Log Labor	0.32***	0.31***	0.31***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***
	(11.95)	(11.70)	(11.64)	(11.69)	(11.73)	(11.76)	(11.80)	(11.83)	(11.87)	(11.91)
Log Materials	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***
	(29.72)	(29.85)	(29.83)	(29.77)	(29.74)	(29.74)	(29.73)	(29.72)	(29.70)	(29.69)
$\alpha = 0.1$	0.21*									
	(2.41)									
$\alpha = 0.2$		0.31**								
		(3.06)								
$\alpha = 0.3$			0.37**							
			(3.21)							
$\alpha = 0.4$				0.34**						
				(3.15)						
$\alpha = 0.5$					0.32**					
					(3.07)					
$\alpha = 0.6$						0.34**				
						(2.87)				
$\alpha = 0.7$							0.38**			
							(2.67)			
$\alpha = 0.8$								0.41*		
								(2.43)		
$\alpha = 0.9$									0.43*	
									(2.19)	
$\alpha = 1.0$										0.44
										(1.95)

Table A.11 Geographic Spillover of Industry-Specific Knowledge, Exporting to Japan

Log Output	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
Age	−0.0088	−0.0085	−0.0082	−0.0083	−0.0083	−0.0084	−0.0085	−0.0085	−0.0085	−0.0085
	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.02)
Log Capital	0.055*	0.055*	0.055*	0.055*	0.055*	0.055*	0.054*	0.054*	0.054*	0.054*
	(2.55)	(2.54)	(2.55)	(2.54)	(2.53)	(2.53)	(2.52)	(2.51)	(2.50)	(2.50)
Log Labor	0.32***	0.31***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***
	(11.85)	(11.71)	(11.61)	(11.63)	(11.66)	(11.69)	(11.73)	(11.77)	(11.80)	(11.83)
Log Materials	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***
	(29.79)	(29.81)	(29.82)	(29.79)	(29.75)	(29.72)	(29.70)	(29.68)	(29.67)	(29.66)
$\alpha = 0.1$	0.37*									
	(2.17)									
$\alpha = 0.2$		0.43*								
		(2.41)								
$\alpha = 0.3$			0.47**							
			(2.67)							
$\alpha = 0.4$				0.43*						
				(2.53)						
$\alpha = 0.5$					0.40*					
					(2.36)					
$\alpha = 0.6$						0.42*				
						(2.16)				
$\alpha = 0.7$							0.41*			
							(1.97)			
$\alpha = 0.8$								0.39		
								(1.81)		
$\alpha = 0.9$									0.37	
									(1.68)	
$\alpha = 1.0$										0.35
										(1.58)

Table A.12 Geographic Spillover of Industry-Specific Knowledge, Exporting to ASEAN

Log Output	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
Age	−0.0088	−0.0085	−0.0084	−0.0089	−0.0089	−0.0089	−0.0089	−0.0089	−0.0089	−0.0089
	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)
Log Capital	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*	0.054*
	(2.50)	(2.51)	(2.51)	(2.52)	(2.52)	(2.55)	(2.56)	(2.56)	(2.57)	(2.58)
Log Labor	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***
	(12.02)	(12.02)	(12.03)	(12.03)	(12.04)	(12.05)	(12.06)	(12.06)	(12.06)	(12.06)
Log Materials	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***
	(29.42)	(29.44)	(29.47)	(29.52)	(29.56)	(29.57)	(29.58)	(29.59)	(29.60)	(29.60)
$\alpha = 0.1$	0.068									
	(0.78)									
$\alpha = 0.2$		0.059								
		(0.67)								
$\alpha = 0.3$			0.058							
			(0.69)							
$\alpha = 0.4$				0.11						
				(1.26)						
$\alpha = 0.5$					0.13					
					(1.40)					
$\alpha = 0.6$						0.13				
						(1.21)				
$\alpha = 0.7$							0.13			
							(1.00)			
$\alpha = 0.8$								0.12		
								(0.81)		
$\alpha = 0.9$									0.100	
									(0.63)	
$\alpha = 1.0$										0.081
										(0.48)

Table A.13 Geographic Spillover of Industry-Specific Knowledge, Exporting to China

Log Output	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J
Age	−0.022	−0.022	−0.022	−0.022	−0.022	−0.022	−0.023	−0.023	−0.023	−0.023
	(−0.05)	(−0.04)	(−0.05)	(−0.04)	(−0.04)	(−0.04)	(−0.04)	(−0.04)	(−0.04)	(−0.05)
Log Capital	0.046*	0.046*	0.046*	0.046*	0.046*	0.046*	0.046*	0.046*	0.046*	0.046*
	(1.97)	(2.03)	(1.99)	(2.05)	(2.06)	(2.07)	(2.07)	(2.04)	(2.04)	(1.99)
Log Labor	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***
	(11.99)	(11.99)	(11.99)	(12.00)	(12.00)	(12.00)	(12.01)	(12.01)	(12.01)	(12.02)
Log Materials	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***	0.66***
	(29.47)	(29.47)	(29.47)	(29.47)	(29.48)	(29.48)	(29.48)	(29.49)	(29.49)	(29.50)
$\alpha = 0.1$	0.16									
	(1.24)									
$\alpha = 0.2$		0.15								
		(1.16)								
$\alpha = 0.3$			0.14							
			(1.07)							
$\alpha = 0.4$				0.13						
				(0.98)						
$\alpha = 0.5$					0.12					
					(0.90)					
$\alpha = 0.6$						0.11				
						(0.81)				
$\alpha = 0.7$							0.095			
							(0.73)			
$\alpha = 0.8$								0.083		
								(0.64)		
$\alpha = 0.9$									0.072	
									(0.57)	
$\alpha = 1.0$										0.061
										(0.49)

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