

Penn Institute for Economic Research  
Department of Economics  
University of Pennsylvania  
3718 Locust Walk  
Philadelphia, PA 19104-6297  
[pier@econ.upenn.edu](mailto:pier@econ.upenn.edu)

<http://economics.sas.upenn.edu/pier>

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“U.S. Venture Capital Meets Clean-Technology”

by

Emanuel Shachmurove, Esq. and Dr. Yochanan Shachmurove

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# U.S. Venture Capital Meets Clean-Technology

By

Emanuel Shachmurove, Esquire

And

Dr. Yochanan Shachmurove

Department of Economics

The City College of the City University of New York, and

Department of Economics

The University of Pennsylvania

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## Abstract

Public concern over global climate change, resource depletion, and environmental degradation has amplified over the last several years, leading to increased demand for environmentally friendly products. Additionally, the price of Clean-Technology products has fallen. This paper examines venture capital investment in the Clean-Technology industry of the U.S. in 1995-2008. The paper explores the effects of macroeconomic variables, national venture capital investment and geography on Clean-Technology investment. The conclusion indicates the importance of geographical location in affecting Clean-Technology investment. A weak correlation between national venture capital and Clean-Technology investments raises the possibility of a more diversified investment portfolio.

**JEL Classification:** C12, D81, D92, E22, G12, G24, G3, M13, M21, O16, O3

**Key Words:** Venture Capital; Clean-Technology Industry; Economic Geography; Location; Environmental Economics; Sustainability; Industrial Sector

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Please address all correspondence to: Emanuel Shachmurove, Email address: mshach@gmail.com

## **U.S. Venture Capital Meets Clean-Technology**

### **I. Introduction**

Public concern over global climate change, resource depletion, and environmental degradation has increased dramatically over the last several years, leading to a greater demand for environmentally friendly products. Additionally, the price of Clean-Technology (Clean-tech) products has fallen over the last few years. These two factors can explain the increase of Clean-tech venture capital investment. However, Clean-tech is being aided by other factors as well. Former Vice President and Nobel Prize laureate Al Gore, a primary figure in the global warming debate, has vigorously lobbied for public policies that favor cleaner production methods. With the change in the U.S. Administration, many analysts expect that the government will introduce public policies which are environmentally friendly. According to Price Waterhouse Coopers, the new stimulus acts of February 2009 devote about \$80 billion out of \$787 billion (about 10 percent) to Clean-tech industry. Furthermore, the December 2009 United Nations Climate Change Conference is expected to place stronger limits on emissions of greenhouse gases in the future. Clean-tech investors and policy makers are anticipating that the weak environmental protections of the Kyoto Protocol will be replaced by more robust ones. In 2008, a record total of 8.4 billion U.S. dollars was spent on Clean-tech investment in North America, Europe, China, and India.

This paper analyzes venture capital investment activity in the Clean-tech sector of the United States during the period 1995 to 2009, Quarter 1 (2009Q1). The Clean-tech sector encompasses those firms that actively incorporate environmental concerns into their products and services. The sector contains environmentally progressive companies from many different traditional, functionality-based industries such as software, energy, telecommunications, etc. The data are taken from The MoneyTree Survey, which is a collaboration among PricewaterhouseCoopers, Thomson Venture Economics and the National Venture Capital Association. Since geography is a likely factor in capital venture investment, this paper uses data that can be stratified into nineteen regions. Furthermore, in order to explore the effects of macroeconomic variables on Clean-tech investment activity, the venture capital data are augmented by Gross Domestic Product (GDP) and a 3-year interest rate based on U.S. Treasury bonds of equivalent length. A 3-year interest rate is used in order to incorporate the effects of interest rates on investment in the high-tech industry.

A long-run perspective is taken in order to explore temporal dynamic movements in Clean-tech venture capital investment. These trends in Clean-tech investment are compared with trends in the aggregate venture capital market. Furthermore, the association between Clean-tech investment and the aforementioned macroeconomic measures is examined. The paper analyzes the data by employing

statistical and graphical methods. Pearson correlation coefficients and regression parameter estimates are used to explore how different variables affect the Clean-tech venture capital market.

The statistical findings lead to several conclusions. First, large scale venture capital investment in the Clean-tech industry is relatively new and has increased dramatically since the beginning of 2006. Hence, in a period when aggregate venture capital activity is decreasing, Clean-tech is undergoing a boom in investment. Additionally, Clean-tech investment is only weakly associated with aggregate national venture capital investment and tends to follow its own independent path over the period. Despite the recent economic crises, Clean-tech investment increased throughout 2008. Only recently, in 2009Q1, has the current global recession caught up to the Clean-tech industry, decreasing venture capital investment activity directed to the sector.

## **II. Literature Review**

The analysis of an industry comprised of environmentally friendly firms is relatively new. Burtis (2004) examines a cluster of Clean-tech firms in California, stating that venture capital investment and government policy are the largest determinants in causing the success or failure of the Clean-tech industry. He argues that one region of the United States will likely become a Clean-tech focal point since venture capital investment tends to be funneled into geographical hubs that become the leaders in their relative industrial sectors. Stack (2006) notes that energy prices, entrepreneurial talent, and technological advances are key factors in the growth of the Clean-tech sector. He suggests that rising awareness over global warming and resource depletion is promoting venture capitalists to invest in Clean-tech firms in expectation of favorable future public policy implementations.

*The Economist* (Nov. 6, 2008) argues that governments will likely support the Clean-tech sector, as related public policy provides stimulus for the economy, while simultaneously addressing global climate change. However, recent decreases in oil prices and stalling credit markets have slowed aggregate venture capital investment, including investment in the Clean-tech sector. Additionally, *The Economist* (May 1, 2008) cites a lack of entrepreneurial talent and stagnation in the development of new technologies as major impediments to present Clean-tech investment. However, the publication argues that the current recession will only result in a short depression in Clean-tech investment. *The Economist* (Nov. 6, 2008) points out that many orders of wind turbines and solar panels have been placed on hold until the national economy recuperates. Hence, the drop in clean energy investment is anticipated to be largely temporary. Furthermore, other countries that pollute heavily such as The United Arab Emirates and China are investing hundreds of millions of dollars in environmentally friendly projects. The need for clean technologies to replace processes based on limited fossil fuel energy will still be present after the economic crisis subsides.

The emergence of the new economic geography can be attributed to the pioneering works of Krugman (Krugman, 1991a, 1991b, 1998) Fujita and Krugman (2004), and Venables (1996, 1998, 2003). Krugman (1991a) examines the uneven economic development of different regions, emphasizing the importance of economic geography in explaining divergent regional development. Krugman (1991b) shows that a country can endogenously become differentiated into an industrialized “core” surrounded by an agricultural “periphery.” Krugman (1998) discusses the emergence of the 'new economic geography,' a new area of research that solves some areas of incongruence in economic theory. It differs from traditional work in economic geography by incorporating a modeling strategy that uses the same technical and mathematical tools found in the 'new trade' and 'new growth' theories.

In the context of venture capital literature, Murphy (1956) provides the pioneering study, based on one hundred start-up firms. The importance of industry choice in achieving start up success has also been studied by others. Shachmurove A. and Shachmurove Y. (2004) explore annualized and cumulative returns on venture-backed public companies categorized by industry. Annual and cumulative returns of publicly traded firms who were backed by venture capital are studied in series of papers by Shachmurove, Y. (2001), and Shachmurove, A. and Shachmurove, Y (2004). Shachmurove, Y. (2006) examines venture capital investment activity in the United States for the years 1996 – 2005. Shachmurove (2007) relates issues in international trade to entrepreneurship, innovation, and the growth mechanism of the free-market economies.

### **III. Data**

The data on venture capital investment activity in the United States is from The MoneyTree Survey. The survey is a quarterly study of venture capital investment activity in the United States (U.S.), which measures cash for equity investments by the professional venture capital community in private emerging U.S. companies. The real Gross Domestic Product (GDP) data is from the U.S. Bureau of Economic Analysis and the 3-year interest rate data is from the Federal Reserve Statistical Release. All the data is from 1995 to 2009, Quarter 1.

### **IV. Empirical Results**

Figure 1 presents Clean-tech investment in terms of dollars and number of deals from 1995 to 2009Q1. As shown in the Figure, Clean-tech investment activity was roughly stable from 1995 to 2005 and then experienced a period of rapid growth from 2005 to 2008. This increase in investment is unique since it took place partly during a recession. Considering the poor economic environment during that time, investment in Clean-tech seems more isolated from downturns in the general economy. However, Clean-tech investment did fall in 2009Q1, indicating that the current global economic crisis may have finally caught up to Clean-tech investment.

Figure 2 displays Clean-tech investment stratified by region from 2007 to 2009Q1. Regional data for Clean-tech investment is not available before 2007. Nevertheless, the Figure clearly shows that Clean-tech investment varies considerably by region, indicating that region is a significant factor in determining Clean-tech investment. Silicon Valley dominates every other region in Clean-tech investment over both the boom and bust periods.

Figure 3 presents the time series of Clean-tech venture capital investment and Real Gross Domestic Product (GDP). Clean-tech investment appears positively associated with GDP. However, Clean-tech investment does not always act in congruence with GDP. The 2006 to 2008 rise in Clean-tech investment occurred during a period of partly slow or stagnant GDP growth. Conversely, the 2009Q1 decrease in GDP is matched by a significant fall in Clean-tech investment. Since aggregate venture capital investment is historically highly volatile, the large decrease in Clean-tech investment is not surprising.

Figure 4 displays Clean-tech venture capital investment and the 3-year interest rate. The 3-year interest rate appears negatively associated with Clean-tech investment until the current recession. Hence, falling interest rates could have contributed to increased investment in the Clean-tech sector. Moreover, the fall in 2008 of aggregate capital venture investment in every other industry helped divert investment to the rapidly growing Clean-tech industry.

Table 1 presents the Pearson Coefficients and their corresponding significant values for the variables used in the study. Clean-tech investment and number of deals of such investment are highly correlated, with a Pearson coefficient of 0.96. As one may expect, real GDP is positively correlated with total investment and Clean-tech investment. However, GDP is more strongly correlated with Clean-tech investment than U.S. aggregate venture capital investment. Furthermore, Clean-tech investment and number of deals are negatively correlated to the 3-year interest rate. This is interesting because aggregate venture capital investment is positively correlated with the 3-year interest rate, indicating that total investment and Clean-tech investment have fundamental differences over the period 1995 to 2009Q1.

Aggregate venture capital and Clean-tech investments have a small correlation (0.07), indicating that there is low association between the two variables. In other words, movements in aggregate venture capital investment do not have a large effect on Clean-tech investment. Total investment and Clean-tech deals have a small negative Pearson coefficient (-0.04), strengthening the conclusion that Clean-tech investment has little association with national aggregate investment over the period.

Table 2 presents the regression results for Clean-tech investment. The adjusted  $R^2$  is 0.80. All variables are significant within the 0.001 level. As may be expected, real GDP has a positive parameter coefficient. Despite the recent rise in Clean-tech investment during the recession year of 2008, Clean-tech investment was still positively associated with GDP over the period. The 3-year interest rate has a

negative parameter coefficient. The date-trend variable has a negative coefficient, while the date-trend squared has a positive coefficient. The parabolic nature of Clean-tech investment could cause a positive association with the square of the date variable, since Clean-tech investment is better estimated with a quadratic time trend than with only the trend variable present (see Figure 1). The rapid increase in Clean-tech investment from 2006 to 2008 broke its previous approximately linear trend. The regular date variable is strictly linear, and thus may be a weaker determinant of Clean-tech investment. To strengthen this conclusion, the residual plot of the date (available upon request) shows larger residual values near the end of the period than does the trend-squared residual plot.

#### IV. Conclusion

This paper examines Clean-tech venture capital investment activity from 1995 to 2009Q1. The statistical results show that Clean-tech investment and aggregate U.S. investment in the venture capital market are not highly associated. From 2006 through 2008, Clean-tech investment increased dramatically, until finally decreasing due to the current recession in the first quarter of 2009. GDP, 3-year interest rate, and time all have dynamic relationships with Clean-tech investment. Unlike other industries which are backed by venture capitalists, it seems that the Clean-tech sector is relatively immune to negative shocks to the U.S. economy. Thus, investment in this sector, as a part of a larger portfolio, may be beneficial by serving as a hedge against downturns in the U.S. as well as the global economies.

**Table 1: Pearson Correlation Coefficients**

N= 10,723. Prob > |r| under H0: Rho=0

	Date	Total Investment	Total Deals	CleantechI	CleantechD	RGDP	IR3
Date	1	0.0477	0.05807	0.70422	0.7829	0.99145	-0.72225
		0.7246	0.6679	<.0001	<.0001	<.0001	<.0001
Total Investment	0.0477	1	0.97594	0.06915	-0.03831	0.13926	0.25701
	0.7246		<.0001	0.6093	0.7772	0.3015	0.0536
Total Deals	0.0581	0.97594	1	0.11532	0.00609	0.15611	0.27109
	0.6679	<.0001		0.393	0.9641	0.2462	0.0414
CleantechI	0.7042	0.06915	0.11532	1	0.96421	0.69636	-0.37121
	<.0001	0.6093	0.393		<.0001	<.0001	0.0045
CleantechD	0.7829	-0.03831	0.00609	0.96421	1	0.76388	-0.44411
	<.0001	0.7772	0.9641	<.0001		<.0001	0.0005
RGDP	0.9915	0.13926	0.15611	0.69636	0.76388	1	-0.66928
	<.0001	0.3015	0.2462	<.0001	<.0001		<.0001
IR3	-0.7223	0.25701	0.27109	-0.37121	-0.44411	-0.6693	1
	<.0001	0.0536	0.0414	0.0045	0.0005	<.0001	

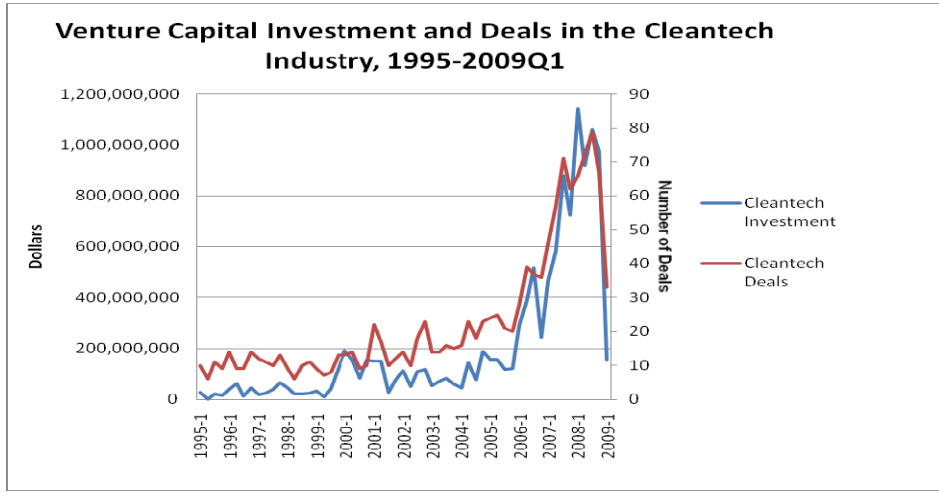
**Table 2: Regression Results for Clean-tech Venture Capital Investment**

Multiple R	0.900707348
R Square	0.811273727
Adjusted R Square	0.796756321
Standard Error	129801724.5

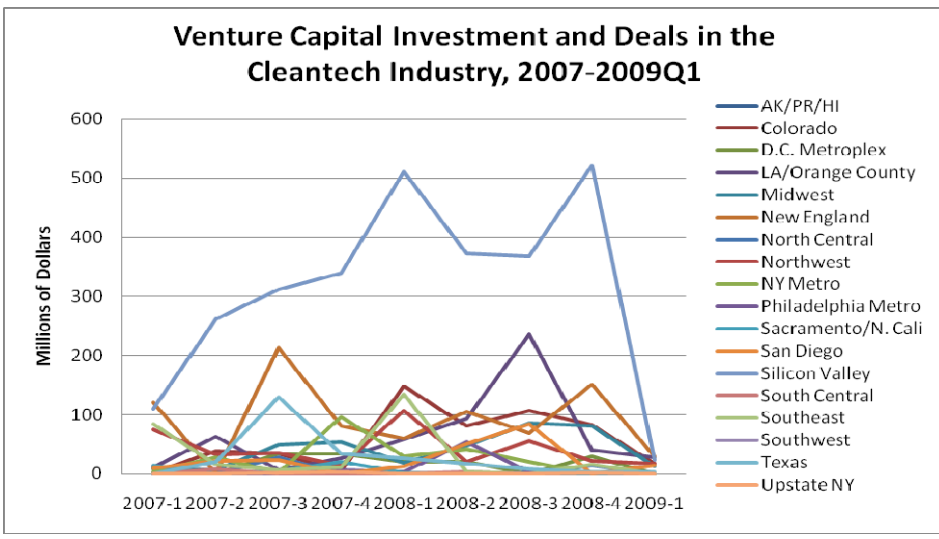
Observations	57				
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	4	3.76616E+18	9.42E+17	55.88283113	3.28019E-18
Residual	52	8.76121E+17	1.68E+16		
Total	56	4.64229E+18			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	-9561232869	1702944590	-5.61453	7.76543E-07	-12978441114	-6.1E+09	-1.3E+10	-6.1E+09
Date (#)	-146694279.2	24174052.21	-6.06825	1.50199E-07	-195203062.8	-9.8E+07	-2E+08	-9.8E+07
Datesquared	1067794.528	126798.7931	8.421173	2.7658E-11	813354.1401	1322235	813354.1	1322235
Real Gdp	1323800.261	236609.742	5.594868	8.33429E-07	849008.0887	1798592	849008.1	1798592
3-year Interest Rate	-94731448.63	27677555.97	-3.42268	0.00121619	-150270526.7	-3.9E+07	-1.5E+08	-3.9E+07

**Figure 1: Venture Capital Investment and Deals in the Cleantech Industry of the United States, 1995-2009Q1**

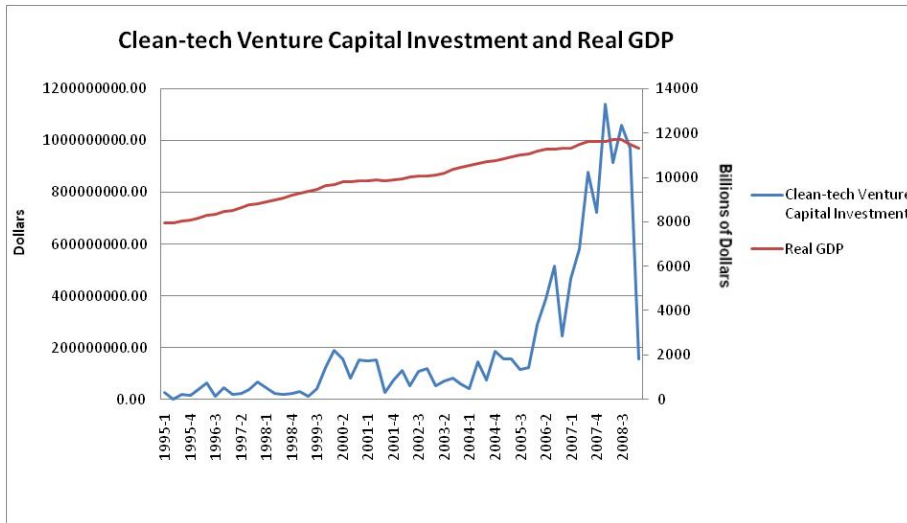


**Figure 2: Clean-tech Investment by Regions, 2007-2009Q1**

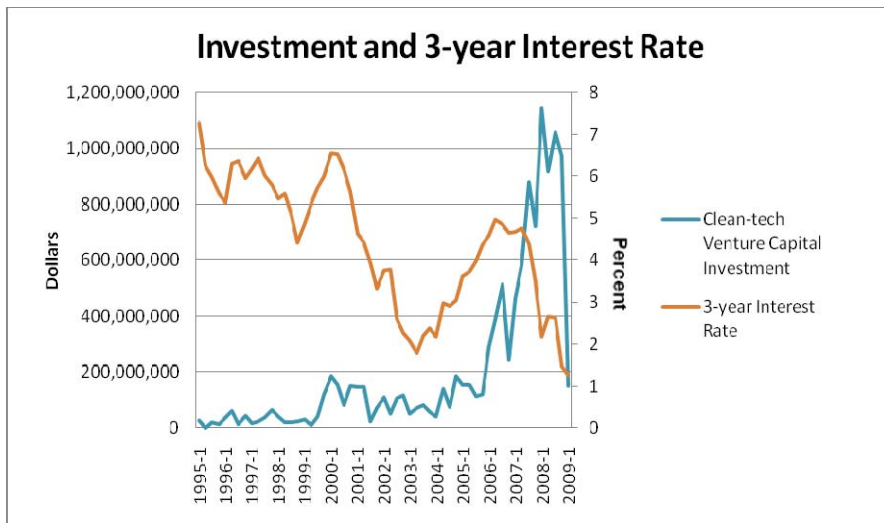




**Figure 3: Clean-tech Investment and Real Growth Domestic Product**



**Figure 4: Clean-tech Venture Capital Investment and 3-Year Interest Rate**



**References**

1. BEHRENS K., Market Size and Industry Location: Traded vs. Non-traded Goods. *Journal of Urban Economics*, vol. **58**, no. 1, pp. 24-44, July, **2005**.
2. BURTIS P., Creating Cleantech Clusters: 2006 Update. *Environmental Entrepreneurs*. **2006**
3. Clean Tech in China. *The Economist* July 19, **2007**.
4. FUJITA M., KRUGMAN P., The New Economic Geography: Past, Present and the Future. *Papers in Regional Science*, vol. **83**, no. 1, pp. 139-64, January. **2004**
5. Gathering Clouds. *The Economist* Nov. 6, **2008**.
6. KRUGMAN P., *Geography and Trade*. Gaston Eyskens Lecture Series Cambridge, Mass. and London: MIT Press, and Louvain, Belgium: Louvain University Press, pp. xi, 142. **1999a**
7. KRUGMAN P., Increasing Returns and Economic Geography. *Journal of Political Economy*, vol. **99**, no. 3, pp. 483-99, June. **1991b**
8. KRUGMAN P., Innovation and Agglomeration: Two Parables Suggested by City-Size

- Distributions. *Japan and the World Economy*, vol. **7**, no. 4, pp. 371-90, November. **1995b**
9. KRUGMAN P., What's New about the New Economic Geography? *Oxford Review of Economic Policy*, vol. **14**, no. 2, pp. 7-17, Summer. **1998**.
  10. Masdar Plan. *The Economist* Dec. 4, **2008**.
  11. MIDELFART K.H., OVERMAN H., VENABLES A.J., Monetary Union and the Economic Geography of Europe. *Journal of Common Market Studies*, vol. **41**, no. 5, pp. 847-68, December. **2003**.
  12. MURPHY T., *A Business of Your Own*, New York: McGraw-Hill. **1956**.
  13. Seeking New Entrepreneurs. *The Economist* May 1, **2008**.
  14. SHACHMUROVE Y., Innovation and Trade: Introduction and Comments, in Eytan Sheshinski, Robert J. Strom and William J. Baumol (eds.), *Entrepreneurship, Innovation, and the Growth Mechanism of the Free-Enterprise Economies*, Princeton University Press, pages 247 -260. **2007**.
  15. SHACHMUROVE Y., An Excursion into the Venture Capital Industry Stratified by Locations and Industries 1996-2005. *The Journal of Entrepreneurial Finance and Business Ventures*, vol. **11**, no. 3, pp. 79 – 104, December. **2006**.
  16. SHACHMUROVE Y., Annualized Returns of Venture-Backed Public Companies Categorized by Stage of Financing. *Journal of Entrepreneurial Finance*, Volume **6**, Number 1, Pages 44 - 58. **2001**.
  17. SHACHMUROVE A., SHACHMUROVE Y., Annualized and Cumulative Returns on Venture-Backed Public Companies Categorized by Industry. *The Journal of Entrepreneurial Finance and Business Ventures*, Volume **9**, Issue Number 3, December, pp. 41-60. **2004**.
  18. STACK J., Cleantech Venture Capital: How Public Policy Has Stimulated Private Investment. *Environmental Entrepreneurs*, May **2006**.
  19. VENABLES A.J., Equilibrium locations of vertically linked industries. *International Economic Review*, **37**: 341–359. **1996b**.
  20. VENABLES A.J., The Assessment: Trade and Location. *Oxford Review of Economic Policy*, vol. **14**, no. 2, pp. 1-6, Summer. **1998**.
  21. VENABLES A.J., Trade, Geography, and Monopolistic Competition: Theory and an Application to Spatial Inequalities in Developing Countries. *Economics for an Imperfect World: Essays in Honor of Joseph E. Stiglitz*, pp. 501-17. **2003**