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Explaining Energy Resource Cooperation: Shale Gas, Chinese Investment, and the Changing Calculus of U.S. Energy Security

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by

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Introduction

In June of 2005, the relatively small and generally insignificant energy company Unocal became the focus of a fierce bidding war. China National Offshore Oil Company (CNOOC) made the first move, outbidding the American firm Chevron. Accepting the CNOOC bid looked like an obvious choice for Unocal since it was almost $1.5 billion dollars more. However, as it became increasingly clear that policy makers in Washington would not allow the deal to go through CNOOC withdrew its bid and Unocal had little option but to accept Chevron's offer.

Washington's opposition seemed to be an overreaction to a deal that would have little immediate or long-term impact on U.S. energy supplies. Unocal accounted for less than one percent of U.S. oil and gas production. The opposition, however, was the product of larger forces. Industry experts and policy makers projected that the world was entering a period of fossil fuel scarcity. Holding energy resources was of vital importance for energy security and national survival. American policy makers found the deal unacceptable. China had a comparable energy demand and deficit. China would likely divert energy products away from the United States and towards itself. Many observers thought that this would be the beginning of what would be a long, drawn-out battle between the two countries over the world's fossil fuel resources. This competition, many believed, would unavoidably strain resources, and scholars such as Michael Klare predicted it would eventually end in war.[1]

In 2005, few would have predicted that the U.S. and China would soon cooperate in the development of energy resources located in the United States. This, however, is what transpired. In 2010, the U.S. allowed a Chinese company to invest in its domestic energy resources. CNOOC, the company that five years earlier had their attempt to invest in

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[1] Michael Klare, *Resource Wars: The New Landscape of Global Conflict* (New York: Henry Holt and Company, 2001).

American energy assets blocked, reached a deal with Chesapeake Energy to help develop and produce shale gas reserves in the Eagle Ford formation in Texas. In 2011, these two companies reached an agreement to develop shale resources in Colorado and Wyoming. A little less than a year later, the Chinese firm Sinopec and the American firm Devon Energy also entered into a joint venture. CNOOC and Sinopec are also currently in competition to buy a 30 percent stake in FTS international, a company that specializes in hydraulic fracturing technology.[2]

Why would U.S. policy makers allow Chinese investment in 2010? This question becomes especially perplexing when taking into consideration that the energy demand for both countries grew during this time, and projections of energy scarcity have persisted. While the shale gas boom has given US policy makers reason for optimism, the amount of gas in the ground or how long it will supply U.S. demand is far from certain. I will offer an explanation for this puzzle by applying the theory outlined by Stephen Brooks in his book *Producing Security*. I will use his theory to create a typology that explains when US policy makers support cooperation and when they do not. I will argue that the United States can no longer seek to obtain energy security independently, or to limit investment only to close allies who pose no threat to energy supplies. High costs and rapid technological development have forced the United States to allow for investment from China, an energy competitor. The United States, however, does not indiscriminately allow for Chinese investment but will only do so when the investment will enable technological innovation and provide needed capital that will further ensure energy security.

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[2] Chris V Nicholson, "Cnooc in $2.2 Billion With Chesapeake Energy," *New York Times,* October 11, 2010; Leslie Hook, "Cnooc Strikes Second US Shale Deal," *Financial Times,* January 31, 2011 ; Dinny McMahon and Chester Yung, "China's Bid in Fracking," *Wall Street Journal,* December 16, 2011.

This paper will continue as follows: I will first provide a review of the relevant literature. I will then offer the theoretical foundations of my argument. I will then give the relevant background information. This will include a brief explanation of natural gas exploration and production as well as a short historical outline of the U.S.-China energy relationship. I will then test two case studies against the hypotheses that I will pose later in this paper. The first case will provide an in-depth examination of the previous attempt of CNOOC to buy a stake in American-held energy assets in 2005. This incident will help provide a baseline of the behavior of energy-deficit states when energy is scarce, or there are projections of scarcity, and there is no pressing need for technological innovation to produce fossil fuel economically. The second case study, U.S.-Chinese shale gas cooperation, will show the response of the United States when projects are technologically and capital intensive.

Reviewing the Literature

There is a considerable body of literature on the role that energy has played in the often rocky U.S.-China relationship. Literature on this subject has dramatically grown since CNOOC's failed bid for Unocal in 2005. While there has been some diversity in the literature, it has largely fallen into Liberal and Realist camps. The Realists see increased demand, shrinking supplies, and limited resource availability leading to increased levels of protectionism and conflict. The Liberals take the approach that the existing institutions and markets will, if they have not already, encourage U.S. and Chinese firms to seek increasing levels of cooperation.

Realists, who see the issue of fossil fuel resources leading to increased conflict between the United States and China, have produced a significant body of work.[3] Those within

[3] The Realist argument is best represented by: Brock Tessman and Wojtek Wolfe, "Great Power and Strategic Hedging," *International Studies Review* 13, no. 2 (June 2011); Michael Klare, *Rising Powers Shrinking Planet* (New

this group vary somewhat in their argument, but they agree on a few key points about the nature of the nexus between energy and U.S.-Chinese relations. These scholars argue that it is China's national interest to aggressively seek energy resources around the globe. The United States views China's behavior as a threat to its energy security. Policy makers, they go on to argue, largely see the acquisition of fossil fuels as a zero-sum game, or that the gain of another energy-deficit country comes at the expense of one's own energy security. Because of this, the United States has sought to protect its current possessions and block further Chinese acquisition. In doing so the United States has not adhered to institutions and treaties, such as the International Energy Agency (IEA) and the Energy Charter Treaty. These treaties and institutions are designed to limit great power conflict over energy resources, but under conditions of scarcity are detrimental to achieving energy security.

While the Realists' argument accurately explained the behavior of the two nations in the four years following the demand shock of 2004, they have been unable to explain the sudden change in behavior towards cooperation in 2008 and 2009. If the logic of the Realist argument were to be followed, it should be expected that considerable efforts would be made to protect new found shale gas assets from foreign investment and possible control. This has not transpired. As domestic resources have become more abundant, the United States has increasingly opened its borders to Chinese investment.

The Liberal argument is that institutional forces have kept, and will continue to keep, Chinese behavior within certain bounds. This group argues that the knowledge that Chinese behavior has increasingly conformed to the guidelines set by institutions, such as international

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York: Metropolitan Books, 2008); Michael Klare, *Resource Wars: The New Landscape of Global Conflict* (New York: Henry Holt and Company, 2001); Ingolf Kiesow, "The Global Race for Oil and Gas: Power Politics and Principles in Asia," *Institute for Development and Security Studies* (October 2008); John B. Alterman and John W. Garver, *The Vital Triangle: China, the United States, and the Middle East* (Washington D.C.:CSIS Press, 2008).

stock exchanges, has increased trust among U.S. policy makers toward China.[4] Those who argue along these lines have pointed to moves such as the listing of China's energy firms on the New York and Hong Kong stock exchanges, closer observance of the guidelines set by the International Energy Agency (IEA), and the ability of the energy market to make mercantilist behavior economically irrational, as evidence of their claims. Instances such as CNOOC's failure to purchase Unocal in 2005, this group argues, are the product of nationalism and domestic politics rather than attempts to achieve or maintain energy security. This group further argues that recent moves toward energy cooperation between the United States and China can be explained best by market forces.

The scholars in this camp accurately point to increased cooperation between the United States and China since 2005, yet their explanations have fallen short of providing a compelling explanation for the change in U.S. policy. Liberals discount the view of U.S. policy makers toward China's investment for most of the 2000s. Policy makers saw energy acquisition as a zero sum game in the years directly following the demand shock of 2004. China's growing energy demand and aggressive investment strategy were a serious threat to energy security. Further, institutions and markets have not constrained Chinese aggression in the acquisition of resources. Since 2005, China has continued to practice the same investment strategy[5]

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[4] This Liberal argument is best represented by the following works: Daniel Yergin, *The Quest: Energy, Security, and the Remaking of the Modern World* (New York: Penguin Press, 2011); Robin M. Mills, *The Myth of The Oil Crisis: Overcoming the Challenge of Depletion, Geopolitics, and Global Warming* (Westport CT: Praeger Publishers, 2008); Edward S. Stienfeld, *Playing Our Game: Why China's Rise doesn't Threaten the West* (New York: Oxford University Press, 2010) Eugene Gohlz and Daryl G. Press, "Energy Alarmism: The Myths that Make Americans Worry about Oil," *Policy Analysis: Cato Institute,* no. 589 (April 2007); Andrei Konoplyanik and Thomas Walde, "Energy Charter Treaty and its Role in International Energy." *Journal of Energy and Natural Resource Law* 24, no. 4 (December 2006).

[5] Cyrus Sanati, "Stockpile of Dollars Drives China's Energy Strategy," *New York Times* Oct 1, 2010; Indira Campos and Alex Vines, "Angola and China: A Pragmatic Partnership," *Center for Strategic and International Studies* (March 2008) , 9-11; International Energy Agency, *2011 World Energy Outlook* (IEA, 2011): 159-161.

My research will provide an alternate explanation, borrowing from both Neoliberal and Realist theories, for the increased tendency toward cooperation between the United States and China. It will be based on the assumptions made by Stephen Brooks in his book *Producing Security*. In *Producing Security,* Brooks lays out a theoretical argument for the analysis of the security implications of the globalization of production. He demonstrates that globalization has changed the relationship between leading international companies. These changes have dramatically shifted the incentives involved in the relationships between major powers away from conquest and towards cooperation and economic integration. The most consequential of these changes has been the incentive to abandon autarkic defense production.

Brooks argues there has been a dramatic shift among advanced nations away from autarkic defense production and towards internationalization, collaboration, and inter-firm manufacturing. Brooks notes that this recent cooperation is in spite of the fact that states desire to continue to produce defense systems domestically. This insight is counterintuitive since there are a number of compelling tactical reasons for desiring domestic defense production. Any deviation from domestic production, therefore, would have to be the product of a compelling security necessity. Brooks provides a convincing answer to this puzzle through his analysis of advanced technology in the defense industry. What he found was that the high costs of research and development, along with rapid improvements in technology, have made autarkic production irrational. This is due to the increased reliance firms have on inter-firm cooperation. The advantages of inter-firm alliances include unique competencies, reductions in redundancies, the advantage of economies of scale, and the ability to share prohibitively high research and development costs. This has allowed firms to make more complicated and cheaper defense systems. Because of the geographic diversity of leading technology firms, firms have disregarded international borders in their search for partnerships in order to produce improved defense systems.

In this research, I will apply this model, with a few modifications, to the energy industry. I will test it against two case studies to see if it offers an explanation for recent U.S-Chinese shale gas cooperation. The question that this research will attempt to answer is*: Have the costs within energy production shifted so that if the United States closes itself off to foreign investment it will be unable to maximize energy production and its energy firms will be unable to continue to develop cutting-edge energy production technology?* In order to create a framework that will answer this question, this research will operate under a number of assumptions of state and firm behavior. These assumptions of state and firm behavior share some of the same traits as those provided by Brooks.[6] As with Brooks' analysis, I will assume that when a state chooses to allow foreign investment in its domestic energy resources, it will only do so if the benefits of foreign investment significantly outweigh the costs. I will further argue that energy resources are a strategic national interest. As such, nations will prefer autarkic energy production, or if that is not possible, to limit investment in such resources to close allies. More specifically, I will argue that the U.S. has changed its position with regard to Chinese energy investment because the benefits of added energy security that come with increased technological research and development made possible by Chinese investment and cooperation have significantly come to outweigh the benefits of autarkic production.

[6] It is important to note, that unlike weapons and weapons systems, fossil fuels are a finite natural resource. Further, fossil fuels can only be produced to the point that the resources are in the ground and only at the rate that production technology will allow.

Hypothesis

H1: For an energy project, if technological intensity and capital intensity are high, it is likely U.S. policy makers will support cooperation and allow for foreign investment.

H 2: For an energy project, if technological intensity and capital intensity are low, it is not likely U.S. policy makers will support cooperation and allow foreign investment.

Dependent Variable: U.S. - Chinese cooperation

Independent variable #1: Technological intensity

Independent variable #2: Capital intensity

Definition of Technology: Any new or improved product, process, or technique that enhances the overall result compared with the result observed today.[7]

I will test the hypothesis against two cases. The first case will be the attempted purchase of Unocal by CNOOC. The second case will be U.S.-China shale gas cooperation that began in 2010. These are the best cases to test the hypothesis. The first case will set a baseline of the expected behavior of states. The expected behavior of states under conditions of scarcity, or projections of such, is to resort to mercantilism. The second case is also an excellent test of the hypothesis. There is little reason to expect the United States to abandon protective policies towards Chinese investment without the inclusion of the independent variables, technology and capital intensity. Both the United States and China have, and continue to face, large energy deficits. Most Realists would argue that such a condition should lead the two states away from cooperation and toward increased levels of protectionism and conflict. This has not transpired.

[7] National Petroleum Council, "Topic Paper #29 Unconventional Gas," *NPC Global Oil and Gas Study* (July 2007):35-36.

Both the United States and China have the potential to secure long-term natural gas security contingent on the continued technological innovation needed to extract unconventional shale gas. As it has become more economically viable to produce shale gas, it has been increasingly beneficial for U.S. and Chinese firms to seek inter-firm collaboration to extract resources. Importantly, for this research, U.S. policy makers have also found it within the interest of U.S. energy security to allow for such investment.

There are a number of differences between the two cases used for this study. The two crucial differences in these cases offer two alternate variables that could explain the change in U.S. policy. The most important of these differences is the nature of the investment. In the first case, CNOOC attempted to purchase Unocal while, in the second case, the Chinese firms bought shares of U.S. shale assets. It could be argued that this difference is the variable responsible for the change in U.S. policy. This explanation is lacking. Any foreign investment by a competitor that is not a net benefit to U.S. energy security will not be permitted. Since U.S. companies primarily drilled for conventional gas prior to 2005, their projects were not comparatively capital- and technology intensive. Further, it can be expected that if an investment similar to that attempted by CNOOC in 2005 was to be attempted today it would only be allowed if the benefits to U.S. energy security significantly outweighed the costs. It is also expected that if a Chinese firm were to attempt to purchase a share in a project, in 2005 or presently, that was not technology and capital intensive, it would be blocked.

Different policy makers between the cases could also be offered as an explanation for the change. The model used for this research assumes rationality. Policy makers do a cost-benefit analysis when deciding to allow or block foreign energy investment. While there has been some variability in U.S. energy policy since the demand shock of 2004, it has been fairly consistent across both major parties.[8] This consistency is evidenced by the nearly unanimous opposition by the House of Representatives to the Unocal-CNOOC deal in 2005, bipartisan support for the energy bills of 2005 and 2007, and the lack of opposition from policy makers of both parties toward Chinese investment in U.S. shale gas. Further, it should also be the case that energy resources directly affecting U.S. energy security, like the Canadian tar sands, continue to be seen as a zero-sum game. The United States has put considerable pressure on Canadian policy makers to block Chinese investment. The United States has attempted to ensure that future energy supply from these resources goes to the United States and not to China, although domestic politics are stalling the proposed Keystone pipeline.[9]

If the hypothesis is correct, after the introduction of the independent variables we can expect to see a number of outcomes. It should be shown that there is a significant need for continued technological development. Further, it should also be the case that U.S. energy companies find it difficult to independently raise the requisite capital for technological development. It should also be expected that firms will meet capital demands by increasing the quantity and quality of inter-firm partnerships between US and Chinese companies. If the hypothesis is correct, then increased cooperation on issues of energy extraction between the United States and Chinese policy makers should be expected. Along with this cooperation there should be a willingness by policy makers within the United States to allow foreign investment in energy assets. If the hypothesis is not correct, in cases where high levels of technology and capital are needed, cooperation between the United States and China should not be expected. In this case, inter-firm partnerships between Chinese and American companies are not likely.

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[8] It should be noted, that while parties' policy choices have remained consistent, the parties' rhetoric has, at times, diverged.

[9] Jeremy Martin, "U.S. must Consider Energy Security in Canadian Oil Debate," *World Politics Review,* September 27, 2011.

Theoretical Foundations

The Behavior of the State

States view fossil fuels as a strategic asset for both economic and military reasons. Fossil fuels provide energy for transportation, production of electricity, industry, heating of buildings, and modern militaries. A nation will prefer to produce fossil fuels domestically and rely on foreign sources and investment as little as possible.[10] Although energy independence is the ideal, the reality for most industrialized states lies somewhere between independent production and heavy reliance on foreign energy sources. Since energy independence is unrealistic for most states, they instead seek energy security.

The term energy security is difficult to define. Daniel Yergin, however, has provided a popular and widely accepted definition: the state's ability to ensure an adequate supply at a reasonable price.[11] This definition is adequate under normal conditions but needs to be expanded to explain state behavior under conditions of scarcity and projected scarcity. Under such conditions, states will seek adequate supply to meet their demands, but possession of resources is more important than price. Since domestic supply is the most secure, it should be expected that a state will aggressively guard domestic resources in order to limit reliance on imports.[12] The addition that this research will seek to make is that states will allow for investment in energy assets by a competitor if the investment has the potential to increase future supply.

[10] Hans Morgenthau, *Politics Among Nations: The Struggle for Power and Peace* (New York: McGraw-Hill, 1948), 115-117.
[11] Daniel Yergin, "Ensuring Energy Security," *Foreign Affairs*, March/April 2006, 70-71.
[12] Theodore Tsakiris, "Energy Security as Economic Statecraft: a Concise Historical Overview of the Last 100 Years," *Agora Without Frontiers* 9, no. 4 (2004):307-329.

The ideal condition for policy makers of most nations is that supply adequately meets current demand as well as projections of future needs. Under such conditions price and distribution are the paramount concerns of policy makers. Policy makers have significant incentive to secure energy resources at the lowest prices possible. Increases in the cost of energy can create serious economic and political problems. Consumers spend money on energy they would have otherwise spent on consumer goods, if prices were lower. The prices of transportation and production also go up as energy for the production of manufactured goods becomes more expensive. In the long-term, if dramatic increases in price go unchecked, the economy will likely shrink, and consumer buying power will diminish. This scenario could have significant political ramifications. Reelection would be unlikely for a leader in a democratic system.[13] Policy makers have an incentive to keep energy prices low. This is achieved by ensuring that energy production and imports will be able to meet current and projected demand while also ensuring spare capacity.

Under the scenario of fossil fuel scarcity, or projections of scarcity, the behavior of energy deficit states will shift dramatically. Energy resource acquisition is a zero-sum game; under conditions of scarcity one state's gain is another state's loss. States with a large energy deficit will aggressively guard their domestic reserves as well as the relationships and energy contracts made with foreign energy producing nations. Energy-deficit states will most aggressively guard these assets against other deficit states.[14]

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[13] U.S. Energy Information Administration, "Economic Effects of High Oil Prices," *Issues in Focus,* 2006.
[14] Klare, *Rising Powers Shrinking Planet,* 33-37.

Energy-Producing Firms and the State

Policy makers have substantial incentives to ensure that their nations have adequate energy supply. Energy-producing firms are the instruments policy makers use to achieve energy objectives. To ensure the proper management of fossil fuel production, many nations have nationalized firms within their borders. This is not the case in the United States. The United States government has no direct control over the companies within its borders, but policy makers are able to exert a considerable degree of indirect control. This influence has historically taken the form of tax breaks, financial incentives, research and development funding, military protection, and aggressive diplomacy for more open access to a producing nation's reserves.[15]

The relationship between Chinese firms and their government is somewhat different. These firms are a hybrid of state and private ownership with a majority stake held by the central government. Chinese firms receive direct mandates from the central government. These mandates, however, are often vague and meant to direct the firms towards general goals and not dictate day-to-day operations or business operations, which few policy makers have the expertise to understand.[16]

Under conditions, or projections, of future scarcity states will push for or mandate the expansion of capabilities and output of the firms under their control. Since dramatically increased production in a country with an energy deficit is often not a realistic goal, these firms must aggressively seek sources outside their borders in order to meet their government's wishes.

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[15] *U.S. Energy Policy Act of 2005*, HR 6, 109th Cong., 1st sess.,(August 8, 2005); *U.S. Energy Independence and Security Act of 2007*, HR 6, 110th Cong., 1st sess., (January 12, 2007).
[16] Yuanyuan Ding, "The Party, the Oil Companies, and Energy Security: Who Determines Chinese Policy?" (Master's Thesis, Georgia State University, 2008).

Nations, under this scenario, will use diplomacy on behalf of such firms since these assets are likely to be contested by multiple deficit nations, and gaining access will be difficult.

Behavior of Energy-Producing Firms

An energy-producing firm's main incentive is to make a profit. Firms make profits by possessing energy resources and extracting product out of these resources at an economically viable rate. As societies have continued to use fossil fuels, these fuels have become increasingly difficult to extract. Continued expansions in production require both large amounts of capital investment, as well as increasing levels of technological development and skill.[17]

Capital Investment

Attempts at fossil fuel extraction are expensive and risky. Although technology has helped to mitigate some of the risk associated with drilling for fossil fuels, any company that undertakes fossil fuel extraction faces serious financial risks. Firms risk being unable to locate resources, or not finding the requisite amount for economic production. The technology to find and produce fossil fuels has also become increasingly expensive to develop and operate. Along with the costs associated with technology and extraction are a number of associated costs. These costs include elements outside of direct production such as government taxes, royalties, and transportation. Few companies, especially smaller independents, have the capital to take on the high costs and risks of fossil fuel exploration and production by themselves. To counter this, they seek outside sources of capital.[18]

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[17] Joseph A. Tainter and Tadeusz W. Patzek, *Drilling Down: the Gulf Oil Debacle and Out Energy Future,* (New York: Copernicus Books Springer, 2011), 65-96.

[18] Frank Jahn, Mark Cook and Mark Graham, *Hydrocarbon Exploration and Production*, 2nd ed., (Aberdeen U.K.: Tracs International Consultancy, 2008), 338-39.

Energy companies raise money either through loan capital (debt) or shareholders (equity). Equity capital within the energy industry often consists of joint ventures between two or more energy-producing firms. Companies enter inter-firm alliances with strict agreements about capital investment, profit sharing, and the role that each company plays in the fossil fuel extraction process.[19]

Technology

The technology to extract hydrocarbon resources has become increasingly complicated and complex. The need to extract from increasingly difficult formations and locations has been the driver for much of the increased complexity in extraction technology. This puts energy-producing firms and nations in a difficult position. Technological innovation is extremely expensive, but as technological capacity increases so does production. A significant increase in production will have the effect of depressing the market price of fossil fuels, making it less likely that a company will recover its research and development costs. However, if a firm were to decide to forgo technological development, it would soon find its technology obsolete, making it unable to produce its product at an effective price. Firms can meet these challenges by entering into inter-firm alliances.[20]

Along with other advances in technology, the skill of the firm's employees in drilling, hydraulic fracturing, and operations will have a significant impact on the production output of any given well. Acquiring the techniques and skill to develop a successful method of extraction is a complicated process. This process takes years to develop, and many attempts to master. This experience, like technological innovation, comes at a price few companies can take on alone. As

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[19] Jahn, Cook and Graham, *Hydrocarbon Exploration and Production,* 338-39.
[20] Ibid.

with technical advances, firms will also meet the difficulties presented by developing drilling techniques with increased inter-firm cooperation.[21]

Inter-firm Cooperation

Inter-firm alliances are short-term ventures that allow for benefits that would not be realized if the firms chose not to cooperate. Energy firms choose to engage in inter-firm alliances for the same reasons that companies in other high entry cost industries choose to do so. In order to stay competitive, as technology continues to advance, firms must adapt and innovate. This process is knowledge intensive, capital intensive, and risky.[22] Inter-firm alliances provide firms with the ability to increase the pace and scope of research and development, reduce costs, and significantly mitigate risks since the resources going towards the effort represent contributions from both partners.[23]

Background

Natural Gas Conventional and Unconventional and Its Uses

Natural gas is the end product of a process that usually takes millions of years to complete. Natural gas is made of decomposing plant and animal life that became buried before it was able to fully decompose. Over millions of years, layer upon layer of sediment, mud, and sand covered these organisms. These layers prevented the normal oxidation process and impeded the process of decay that organic matter usually undergoes. Over time, these layers of sediment became compacted into rock formations. Over the span of millions of years, the weight of these rock

[21] Robin Beckwith, “Hydraulic Fracturing: The Fuss, the Facts, and the Future,” *Journal of Petroleum Technology* (December 2010), 34-41.
[22] ibid
[23] Stephen G. Brooks, *Producing Security: Multinational Corporations, Globalization, and the Changing Calculus of Conflict,* (Princeton NJ: Princeton University Press, 2005), 31-38.

formations as well as the earth's heat turned these trapped organisms into natural gas buried deep below the earth's surface.[24]

Natural gas comes in two forms. There is associated natural gas, which formed in conjunction with oil, and nonassociated gas, which formed independently of oil. During production, associated gas is a secondary product in the search for more valuable oil, while nonassociated gas is the primary product. Both associated and nonassociated gas can be found in a wide variety of locations and geological formations. Both types are found in geologic formations that are considered either conventional or unconventional. The classifications of conventional and unconventional resources are particularly relevant for the purposes of this paper. Conventional natural gas is found in well-defined and permeable rock formations. Gas distributed around a large area where permeability is low is unconventional gas. However, the most salient distinction between conventional and unconventional resources is the level of technology needed for economical production. Unconventional gas resources are shale gas, tight gas sands, coal bed methane, and methane hydrates. These resources require higher levels of technology and cannot usually be economically extracted with the use of vertical wells. The technology needed for economic extraction makes unconventional resources much more expensive than conventional resources to extract.[25]

Natural Gas in the Energy Equation

Natural gas has a wider variety of worldwide uses than any other fossil fuel. Gas's share of the energy market has grown significantly, and its growth will continue as its use expands. Natural gas comprises twenty-four percent of worldwide energy consumption and is crucial to a number

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[24] Bob Shively and John Ferarre, Understanding *Today's Natural Gas Industry*, (Energydynamics, 2007),7.
[25] International Energy Agency, "Global Surge of Activity Follows Surge of Unconventional Gas in U.S.," *IEA Analysis* (January 2011).

of segments of leading economies. In the United States, natural gas produces forty percent of the energy demanded by industrial production, eighteen percent of electricity production, seventy percent of the fuel consumed to heat homes and stores, and three percent of the fuel consumed for transportation.[26]

In light of the important role of natural gas in the energy equation, securing this resource is vital for energy security. Although natural gas is not at the forefront of public discussion, securing access to this vital resource is at the forefront of policy makers' agendas. In the United States, promotion of increased domestic natural gas production has been the target of a number of pieces of legislation stretching back to 1980s. The first piece of legislation was Section 29 of the Windfall Tax Bill of 1982. The object of this bill was to provide incentives for the exploration and production of unconventional natural gas resources. Without these incentives, there would have been few attempts to extract unconventional resources since they would not have been economical.[27] Natural gas was also the target of key pieces of the 2005 Energy Policy Act, the 2007 Energy Security and Independence Act, and the energy policies put in place by the Obama administration.[28]

U.S. Natural Gas Scarcity

At the turn of the 21st century, there was considerable concern that the United States would soon become a net importer of natural gas. This scenario would be extremely costly. Because natural gas comes out of the ground in gas form, it is extremely costly to ship across oceans. A problem once thought to be a distant threat became immediate and real as U.S. natural gas consumption

[26] MIT, *Future of Natural Gas*, 4-5.
[27] Yergin, *the Quest,* 326-27
[28] Laurence R. Geri and David E. McNabb, *Energy Policy in the U.S: Politics, Challenges, and Prospects for Change* (Boca Raton: CRC Press, 2011), 71-79.

dramatically grew throughout the 1990s. This increase was largely due to a major shift in the production of electricity. Power plants operators started to move away from the use of coal and oil and towards natural gas. At the time producers of electricity were making this switch there was little fear that natural gas would become scarce, or that prices would significantly increase. However, throughout the 1990s and early 2000s U.S. producers of gas found that they were able to produce and find less natural gas. This became a concern for both producers of gas and electricity, as well as policy makers. Policy makers knew that if the price of gas were to increase due to expensive imports then consumers would be faced with higher utility and heating costs.[29]

Nearly all energy agencies predicted that the United States would soon face a gas deficit. The IEA predicted in 2003 that the United States would not be able to sustain consumption at the 2002 rate (Table 1). If the United States continued these levels of consumption, then by 2010 it would be forced to import large amounts of natural gas. Demand was growing at a rate of two percent a year, while production was growing at a rate of only one percent. The picture for Canada's production output, which had made up for the United States' twenty percent deficit, would not grow fast enough to meet the U.S.' increasing demand.

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[29] Yergin, *the Quest,* 319.

Table 1. Projections of U.S. Natural Gas Consumption.

Year	2003	2010	2025
	Consumption		
	22.0	26.2	31.4
	Supply		
Lower 48	18.6	19.9	21.3
Alaska	.5	.6	2.7
Canada	3.5	3.7	2.6
Mexico	-.6	-.3	-.1
LNG	.4	2.2	4.8
Other			
Total	**22.4**	**26.2**	**31.4**

source: IEA *World Energy Outlook 2004*

As can be seen from the data presented in Table 1, the projections provided by the IEA gave the United States considerable reason to be concerned about its ability to provide for its short-and long-term needs.

Projections of scarcity encouraged energy companies to devote large amounts of capital toward the infrastructure needed to produce, store, and ship vast amounts of natural gas.[30] Natural gas is ideally transported over long distances in pipelines. In order for natural gas to be shipped across an ocean, it must be changed from a gaseous state into a liquid (LNG). Liquefied natural gas is made by cooling gas to the point where it becomes liquid (-260°F). This liquid is then pumped into specially designed ships that can maintain this temperature for extended periods.[31] This is an extremely complex and difficult process. It is also extremely expensive, but necessary, in order to meet future import needs of large deficit countries like the United States and China. The large scale investment needed for infrastructure and production of LNG was not

[30] Majors are energy companies who are involved in extraction, productions, and distribution of energy products. Independent energy companies are only involved in the extraction of energy products.
[31]Shively and Ferarre, *Understanding Today's Natural Gas Business,* 11*;* MIT, "The Future of Natural Gas*,*" 35.

the United States' sole concern. There were also serious concerns about the geographic locations of many of the large natural gas reserves. Not only were many of these reserves in distant countries, but many were countries with which the United States had rocky relationships. Policy makers feared natural gas would now face many of the same security and price issues as oil. These included issues such as transport and security, and increased competition with China.[32]

Growing Chinese Demand for Natural Gas

The demand for natural gas in China has grown rapidly. This increase stems from two sources. Chinese policy makers need to provide energy for rapid industrial growth. They also desire to curb the environmental damage done by the use of coal for heating homes and producing electricity.[33] These forces have dramatically increased demand for natural gas and strained domestic resources, which are limited and underdeveloped.

Although in 2005 Chinese demand for natural gas resources had not yet outstripped production, it was assumed that it soon would. Chinese policy makers would soon be faced with severe shortages. These shortages had the potential to damage economic development and slow the pace of further modernization. In 2004, China imported its first significant quantities of LNG, a trend that has continued and grown (Table 2). At present, the natural gas deficit has forced China to import large amounts of LNG to meet domestic demand.[34] Chinese energy firms have aggressively sought natural gas reserves to make up for this deficit. In 2004 alone, Chinese firms signed long term deals for LNG imports from an Australian gas producer, the Iranian

[32] Yergin, *the Quest,* pgs. 312-316..
[33] Duan Zhaofang, "China's Natural Gas Market Outlook," *The 4th CNPC/IEEJ Press Conference of Oil* (December 10, 2010).
[34] Duan Zhaofang, "China's Natural Gas Market Outlook," *The 4th CNPC/IEEJ Press Conference of Oil* (December 10, 2010); IEA, "Natural Gas Market Outlook,"139-142.

National Oil Company, and various gas-producing African nations. The Chinese also began to pursue natural gas deals in the central Asian country of Kazakhstan.[35].

Table 2. Chinese Natural Gas Imports	
Year	Chinese LNG Imports (tons)
2003	0
2004	483
2005	483
2006	687,543
2007	2,913,122
2007	3,336,000
Source: Gas in China	

The Chinese government's global search for natural gas security led them on a collision course with the United States. U.S. and Chinese firms were aggressively going after the same gas resources at various locations around the world.

Case #1: CNOOC- Unocal

The Unocal-CNOOC case began in late 2004. CNOOC had expressed some early interest in Unocal, but quickly dropped out due to fears of taking on too high a debt burden. At this point Chevron, a large American energy firm, offered a bid that the board of Unocal deemed to be too low. In response, Unocal's board informed CNOOC of Chevron's unacceptable offer and asked if they would be willing to reconsider and make a counter offer. Unocal's board also told

[35] China Daily, "China, Kazakhstan Discuss Cross Border Pipeline," *China Daily,* August 25, 2004.

Chevron that they would entertain Chevron's offer if it was increased. Chevron jumped at the second chance and was the first to offer a new bid of $16.5 billion. A few weeks later this bid would be outdone by CNOOC, which made an unexpected all cash-offer of $18.5 billion.

The misconception in the general public, and in some of the articles put out by the press, was that CNOOC wanted to acquire Unocal for its oil assets. This was not the case. Unocal was a minor player in the oil industry, but held large reserves of natural gas. Natural gas made up sixty percent of the company's assets. Unocal's reserves were located throughout the world, but most were in Southeast Asia.[36] The geographic location of these assets is what made them appealing to both firms. Both firms thought that Unocal's LNG technology and reserves would be a valuable addition to their portfolio. Both firms also wanted to increase their share of the Chinese market.[37] Chevron, however, had a number of domestic reasons for wanting to acquire Unocal. If natural gas supplies in the United States became more constrained, it would have the facilities and capabilities in place to begin importing LNG from production points in Southeast Asia.[38] The possibility of allowing a reliable source of future LNG imports to be bought by a company from China presented too much risk for policy makers.

Although there was some incentive for cooperation between U.S. and Chinese companies, this incentive outweighed the energy needs of the firms' home country. Holding assets currently under development is more likely to lead to energy security than developing technology that may have uncertain results. Also, importantly, there was little need for an American company to seek or want Chinese capital. Since these thresholds are not met, cooperation is not expected

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[36] David R. Baker, "Chevron Completes Unocal Deal: Purchase Spells the End of 115 Year Old Company," *San Francisco Chronicle,* August 11, 2005.
[37] Steinfeld, *Playing Our Game,* 201-204.
[38] Klare, *Rising Powers Shrinking Planet,* 4-5.

Technology and Investment

In 2005, Unocal was a company with a checkered past. The company, although spending billions in capital throughout the early 2000s, was unable to make any significant finds. Through 2004, both production and reserves had steadily declined. By 2005, many of the firm's fields that were not already under production or online for production were considered marginal. Although this was the case, the company remained profitable due to the rising prices of oil and gas. In 2004, the company recorded a record profit of $1.21 billion, nearly double their previous record from the year before of $643 million. Unocal's profits and large reserves were an easy way for CNOOC and Chevron to increase natural gas reserves and profit margin. In 2005, with limited exploration, guaranteed production and proven reserves were exceedingly lucrative. [39]

Many energy-producing companies believed that purchasing assets, like those held by Unocal, would be cheaper than hiring the work force, developing the technology, and taking the risk in capital that large-scale exploration projects demanded. [40] Even if firms had wanted to take on serious exploration efforts they would have been extremely limited in their ability to do so. Many large firms had long-term financial obligations and had a limited numbers of workers skilled in fossil fuel exploration. [41] It was for these reasons that Chevron and CNOOC wanted to acquire Unocal.[42]

Under the scenario described above, there was little need for technological development or cooperation. Unocal's assets had largely been developed with existing technology. Further,

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[39] The Funding Universe, "Unocal Corporation." *Funding Universe,* http://www.fundinguniverse.com/company-histories/unocal-corporation-history (accessed October 4, 2011).
[40] Yergin, *the Quest,* 83-105
[41] Tom Bower, *Oil: Money, Power, and Politics in the 21st Century,* (New York: Grand Central Publishing, 2009), 309-311.
[42] David R. Baker, "Chevron Completes Deal Purchase Spells End of 115 Year Old Company," *San Francisco Chronicle,* August 11, 2005

Unocal was a possessor of conventional assets that did not require advanced drilling and hydraulic fracturing technology to extract. The unconventional resources that they did hold, mainly deepwater sites in Asia and the Gulf of Mexico, were already producing or near production.[43]

If current reserves are not sufficient to meet a nation's demand, then energy firms are encouraged by their governments to grow their reserves and production. Firms achieve this through acquisition of other energy producing companies. These firms will ideally have attractive assets, usually already under production or beyond the early stages of exploration.[44] Although prior to CNOOC's attempted purchase of Unocal in 2005 there had been limited cooperation between Chinese and U.S. companies, this cooperation was mainly for large projects that were in lands foreign to both firms, notably pipeline projects in Central Asia and a couple of offshore projects. These projects were not within the U.S. borders, and the intentions of these projects posed no threat to U.S. energy security. The intention of these projects was for more effective transport of China's existing assets. However, CNOOC's attempted purchase of Unocal was a perceived threat to U.S. energy security. If an investment poses a threat to energy security, policy makers will not allow it. A state will only cooperate with a foreign energy competitor when the benefits significantly outweigh the costs. In this case, the benefits did not outweigh the costs. CNOOC's investment does not meet the threshold set out by this model. The expected outcome is mercantilist behavior from American policy makers.

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[43] Ray Tyson, "Chevron Nabs Unocal: $18.4 billion Deal said Perfect Fit; Company Mum on Sale of Non-Core Unocal Assets," *Petroleum News,* April 10, 2005.

Political Opposition to CNOOC's Investment

Soon after the announcement of the proposed CNOOC-Unocal deal it faced strong opposition from U.S. policy makers. This opposition stemmed from a number of concerns. These concerns included questions about Chinese intentions and the increasing trade deficit. At the forefront, however, was that with nothing to balance the loss of Unocal, CNOOC's acquisition was a Chinese gain and an American loss.

The day after the deal became public knowledge, two congressmen wrote to President Bush urging him to conduct a full ninety day review by the Committee on Foreign Investment in the United States (CFIUS).[45] CFIUS is an organization that has considerable influence on foreign direct investment in the United States. If the CFIUS board gives an unfavorable review judging that the acquisition threatens national security, it is likely that the executive will block the investment.[46] Up until 2005, the president had only blocked one deal of the thousands that had gone under review. CFIUS had done thousands of reviews, but none of them had dealt with the transfer of energy products. However, until 2005 U.S. energy supplies had never been threatened by another energy-deficit country.

Congress also took formal steps to block the sale. On June 30, the House of Representatives passed a bill that disallowed the president from using federal funds to approve the sale of CNOOC. Since the president would not be able to approve of the purchase, the investment would be blocked. The bill passed easily, 398-15, receiving bipartisan support.[47] Congress would take further steps. On July 15, the Senate introduced a bill that would directly

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[45] New York Times, "China Oil Giant Expected to Vote on Unocal Bid," June 22, 2005.
[46] James K. Jackson, "Foreign Investment, CFIUS and Homeland Security: An Overview," *Congressional Research Service,* (March 30, 2011), 1-3.
[47] New York Times, "Foreign Suitors Nothing New In U.S. Oil Patch," July 1, 2005.

prohibit CNOOC's acquisition if the President chose not to act. On July 20, the Senate also passed an amendment that would require the Secretary of State to report to Congress before any attempted purchase of an American asset by a foreign company.[48] Added to these efforts was a provision to the 2005 Energy Policy Act, included shortly after CNOOC withdrew its bid. This addition required that the secretaries of Defense and Homeland Security study the implications that China's rising energy demand would have on the security of the United States.[49]

Policy makers were also outspoken in the press of their opposition to CNOOC's investment. Senator Ron Wyden said, "I am a free trader but being a free trader is not synonymous with being a chump." Senator Max Baucus, said, "China's competitive challenge makes Americans nervous from Main Street to Wall Street, What is the Administration's plan? They have none."[50] Many other policy makers expressed concern over the implications that the deal would have on U.S. energy security via television and radio.[51]

The clearest expressions of the threat posed by CNOOC's investment were given in a hearing held by the House Armed Services Committee. James Woolsey, Frank J. Gaffney, and Jerry Taylor provided the hearing's testimonies. The former two were hawks who adamantly opposed the deal. The latter was a strict believer in free markets and openness to foreign investment. The hearing gives clear indications of the reasons why policy makers blocked CNOOC's investment.

Taylor attempted to convince committee members that the deal posed no threat to the United States. Taylor argued that Unocal was so small that the transfer of ownership would have

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[48] Jad Mouwad and David Barboza, "In Takeover Dance, the Chinese Miss a Step," *New York Times*, July 21, 2005.
[49] Llwelyn Hughes and Sean J. Kreyling, "Understanding Resource Nationalism," *Journal of Energy Security* (July 2010).
[50] Edmund L. Andrews, "Capital Nearly Speechless on Big China Bid," *New York Times,* June 24, 2005.
[51] Steinfield, *Playing Our Game,* 176-177.

little direct effect on energy markets and U.S. energy security. He argued further, that the Chinese would not divert resources currently produced by Unocal since this would make little economic sense. Taylor's arguments proved to be out of step with the opinions held by the committee members. Members from both political parties questioned his motives and his judgment. To them, China posed an obvious and serious threat to U.S. energy security, a problem that could not be mitigated by market forces.[52]

Woolsey and Gaffney both offered similar testimonies. Woolsey's main claim was that Taylor, and others with similar beliefs, were unable to explain Chinese behavior through economic theory. From the economist's view, he argued, the deal made little sense. CNOOC was taking on large amounts of debt that would likely make them unprofitable for years. He believed that in order to understand this issue, one must understand grand strategy. China's strategy was to scour the globe securing whatever energy resources it could find, especially much needed natural gas, to ensure its continued economic growth, and replace the United States as the global hegemon.[53] A member of congress asked Woolsey if he would compare China's aggressive foreign energy policy and grand strategy to that of Japan in 1941. Woolsey replied that Japan in 1941 was a valid comparison. He would add that one could never trust economics because markets do not dictate supply - politics do. He told the committee that if a nation was to rely solely on market forces it could not ensure energy security.[54]

The responses to the testimony of Gaffney and Woolsey were, with few exceptions, positive. Congressman Jim Saxton commented that blocking CNOOC's purchase was not just a

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[52] House Committee on Armed Services, *National Security Implications of the Possible Merger of the China National Offshore Oil Corporation with Unocal Corporation*, 109th Cong., 2005, 16-18.
[53] Ibid, 1-9.
[54] House Committee, *National Security Implications*, 39.

matter of supply and demand, but it was about protecting the national interest.[55] He could not understand why the United States would allow communist China to take possession of strategic assets. Congressman D'Amato would also echo the sentiments of the witnesses when he stated that the Chinese are supply driven, not price driven, and that world energy demand was likely to exceed supply in the next fifteen years, thus making the approval of this deal irrational.[56]

Members of the Bush administration, in spite of fears of future repercussions and a possible trade war with one of America's most valuable trading partners, essentially blocked CNOOC's investment. In a carefully worded statement, Bush's press secretary assured Congress and U.S. citizens that any deal made between Unocal and CNOOC would be the subject of a full CIFUS review. What this meant is that CNOOC's purchase of Unocal would not be allowed.[57]

The findings from this case confirm the hypothesis. Unocal's assets were largely developed, so there was little need for technological innovation or large amounts of capital. The United States behaved as expected and blocked the sale since it would harm U.S. energy security while increasing China's.

Case #2: Shale Gas and Cooperation

This section will examine U.S.-Chinese shale gas cooperation. I will begin by giving a brief history of shale gas in the United States. I will then explain the technological innovations that have made economic extraction of shale gas possible. This is followed by an explanation of how the needs for further technological advancement and capital have pushed U.S. firms to enter into

[55] House Committee, *National Security Implications* , 38.
[56] Ibid, 45.
[57] Edmund L. Andrews, "Capital Nearly Speechless on Big China Bid," *New York Times* June 24, 2005.

joint ventures with Chinese companies. I then will explain why policy makers in the United States have allowed these partnerships to take place.

Brief History of Shale Gas in the United States

The technology that has allowed for economic shale gas extraction has had a transformative effect on world energy markets. It had long been recognized that natural gas trapped in shale rock formations could be found in abundance throughout the United States and the world. In fact, the first natural gas well was drilled into a shale formation in 1821 in Fredonia, New York, but there were few attempts to extract shale gas on a large scale. This was due to inadequate technology for economic extraction. As America's conventional resources of natural gas began to become increasingly scarce, the gas trapped in shale formations became more appealing to energy firms looking to increase productivity and reserves. In order to reach these reserves there would need to be a considerable amount of technological innovation.[58]

One of the first men to try to develop American shale gas reserves on a large scale was George Mitchell, owner of Mitchell Energy and Development, a medium-sized U.S. independent. His began his efforts in 1982 in Texas' Barnett shale formation. His attempts would prove to be difficult and costly. He would spend the next twenty years exploring, experimenting, and drilling, with varying degrees of success. It would not be until 2003, after Devon Energy bought Mitchell and introduced the combination of hydraulic fracturing and horizontal drilling, that the production of shale gas became economically viable. By this time, Devon Energy was the only firm that had not given up on shale gas, but with promises of new technology and America's abundant supply, many companies reentered the market. Since then, there has been a

[58] Yergin, *the Quest,* 325-27.

dramatic increase in domestic natural gas production, which many energy industry experts call "the shale gale."[59]

The introduction of shale gas to the American energy market has had a profound effect on the politics of energy. In 2007 and 2008, energy experts noticed that increased shale gas production had a profound impact on the natural gas market.[60] Since this time, many American politicians have gone from worrying about scarcity and looming natural gas deficits to touting America as an energy superpower. This is evident in President Barrack Obama's 2012 State of the Union address when he claimed that the United States is the Saudi Arabia of natural gas, adding that it possesses enough natural gas to supply its needs for the next 100 years.[61]

The prediction of 100 years' worth of domestic natural gas reserves comes with some caveats of which policy makers are aware. Currently the United States has knowledge of reserves and technology to produce eleven years of natural gas at the current rate of consumption. In order to discover and produce the remaining eighty-nine years of gas, there must be continued investment and technological innovation. A 2011 EIA report highlighted this information. The EIA report hypothesized two scenarios for shale gas recovery: a low shale gas recovery case and a high shale gas recovery case. The low case represents production expectations at current technology exploration and extraction levels. In the low recovery scenario, the United States will become a net gas importer by 2035.[62] In spite of these major reservations, there has been considerable optimism for the future of America's natural gas production by both energy-producing firms and policy makers. This dynamic has played a pivotal role in world energy

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[59] Yergin, *the Quest*, 327-328
[60] Ibid*.*, 329.
[61] Jason Koebler, "Obama: U.S. Saudi Arabia of Natural Gas," *U.S. New and World Report,* January 26, 2012.
[62] Chris Nedler, "What the Frack? Is there really 100 Years of Natural Gas Beneath the United States?" *Slate,* December 29, 2011; Aurthur E. Berman, "U.S. Shale Gas: Less Abundance Higher Costs," *Petroleum Truth Report,* July 31, 2011.

politics and is a crucial variable for understanding U.S.-Chinese cooperation. If the United States allows Chinese investment, it will increase the pace and scope of technological development, as well as ensuring increased supply. If the hypothesis is correct and the United States were to cut off investment, it would do so at a significant cost to current and future energy security, putting it back in the uncomfortable position of once again being a net natural gas importer.

Technological Advances and the Need for Further Development

The ability to extract natural gas economically from shale formations has been the product of technological innovation in two areas. These are hydraulic fracturing and horizontal drilling. These will be examined to show how the impact of technological innovation, as well as cost, has transformed the natural gas industry. This is followed by a discussion of the further technological development needed for U.S. energy firms to be able to maximize domestic resources.

Hydraulic Fracturing

Hydraulic fracturing is the process of pumping a high volume of fluid at a high pressure into a well. This creates tiny fissures in the rock surrounding the well. These fissures allow the gas to flow out of the rock and to the collection point at the top of the well. Ultimately, this process increases production to economic levels in wells that might not otherwise be considered viable. This process has required a significant degree of technological advancement for it to be used on technically complex shale formations.[63] These advances have mainly been in mixing and blending equipment and fracturing fluid compounds.

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[63] Chesapeake Energy, “Barnett Shale Hydraulic Fracturing: Fact Sheet,” (January 12, 2012), http://www.chk.com/media/educational-library/fact sheets/barnett/barnett_hydraulic_fracturing_fact_sheet.pdf (accessed February 8, 2012).

Since the first hydraulic fracturing job in 1949, the technological advances in pumping and blending equipment have been astounding. The equipment used to hydraulically fracture the first wells were capable of producing only 75 hhp.[64] Currently, hydraulic fracturing equipment can produce over 1,500 hhp. The pump rates that higher-power pumping machines are capable of also significantly increased. In the 1970s, fracturing equipment was only able to achieve rates of two to three bbl/min.[65] Currently, the minimum pump rates required to fracture shale formations are around one-hundred bbl/min. These increases in capacity can be attributed to the development, and continuing development, of specialized equipment rather than dual use technology employed in earlier jobs. This specialized equipment includes intensifiers, slingers, and manifolds.[66]

In order to fracture a shale formation properly, a precise blend of proponents needs to be added to the fluid. These proponents ensure proper fracture in the shale formation as well as keeping the fractures open after the pumping has stopped. High-tech equipment, such as specialized computers and storage systems, is needed in order to ensure the proper blend. These technologies have been the product of extremely expensive industry-specific technological innovation. Without these advancements in blending equipment, fracturing fluids would not be nearly as precise, nor would they be nearly as effective.[67]

These technological advances have made shale gas production possible. However, they have also had the effect of dramatically increasing the equipment costs of hydraulic fracturing service companies. In order for energy companies to drill effectively, they must now have millions of dollars' worth of equipment, as well as continue spending to stay on the cutting edge

[64] Hydraulic horse power (HHP)
[65] Oilfield barrel per minute (bbl/min)
[66] Montgomery and Smith, "Hydraulic Fracturing," 28.
[67] Ibid, 27.

of the relevant technology.[68] Oil and Gas service companies have been unable to absorb these dramatic price increases and have passed on many of the costs to the service firms with whom they contract. This is most clearly evidenced by the difference between the levels of research and development dollars invested by service companies, and those invested by oil and gas companies. In 2011, it is estimated that that Schlumberger, one of the largest service companies, spent 2.6 percent of its total revenue, respectively, on research and development. Schlumberger's high levels of investment are not unusual among service companies. In the same year, Halliburton and Baker Hughes spent 2.4 percent and 1.7 percent of their total revenue on research and development. In contrast, BP, Royal Dutch Shell, and Exxon Mobil, each spend less than 0.5 percent of their total revenue on research and development.[69]

The technology involved in the production and implementation of fracturing fluid and proponents have also dramatically improved. Hydraulic fracturing fluid largely consists of water and sand. The amount of sand and water used in fracturing fluids has changed over time and has been the product of vast amounts of research and experimentation. The size and type of sand have also been heavily researched and experimented upon.[70] Other products are added to the mix to ensure that hydraulic fracturing is done safely and effectively. These additives include acid, an antibacterial agent, a breaker, a clay stabilizer, a corrosion inhibitor, cross linkers, a friction reducer, a gelling agent, iron control, a pH adjusting agent, a scale inhibitor, and a surfactant.[71] Since each formation is unique, the amount and type of additive to be included is adjusted to meet the needs of specific fields. These changes are made after experimentation in both the lab

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[68] Montgomery and Smith, "Hydraulic Fracturing," 31-32.
[69] Aberdeen, "The Unsung Masters of the Oil Industry: Oil Firms You Have Never Heard of are Booming," *The Economist*, July 21, 2012, http://www.economist.com/node/21559358 (Accessed July 21 2012)
[70] Montgomery and Smith, "Hydraulic Fracturing," 26-27.
[71] Chesapeake, "Hydraulic Fracturing Fact Sheet." Energy companies do not make the specific contents of their compounds public. These compounds are considered trade secrets.

and the field. Hydraulic fracturing fluid can be expected to continue to change as the industry learns more in the lab and has more experience in the field.[72]

Horizontal Drilling

Horizontal drilling is the second piece to the technological puzzle presented by shale gas reserves. Horizontal drilling is the process of drilling down to a certain depth and then adjusting the drill so that it continues at an angle. Horizontal drilling's first commercial use was in the early 1980s, but it was not until Devon Energy bought out Mitchell Energy in 2001 that this technology was used for the production of shale gas.[73]

The application of horizontal drilling was the product of a number of advances in directional drilling technology. These advances have allowed the drill operator to have greater control, as well as knowing the precise depth of the drill when it is in the ground. This has given the operator greater ability to more precisely change the direction of the drill, as well as allowing the operator to drill multiple bore holes. This allows for the precise placement of production equipment in the well, optimizing extraction and increasing the likelihood of successful drilling.[74]

The ability to drill horizontally has also been the product of experimentation in the field. The success of the well is as dependent on the ability of the drill operator as it is on the advanced mechanical technology. The knowledge necessary for an operator to drill horizontally effectively only comes through experience and experimentation. Devon's first attempts to apply the process in the Barnett Shale Formation are evidence of this. In 2002, the first year, they drilled 7 wells.

[72] Carl T. Montgomery and Michael B. Smith, "Hydraulic Fracturing,"28.
[73] Yergin, *the Quest,* 328-29.
[74] Lyn Helms, "Horizontal Drilling," *North Dakota Geological Survey* 35, no. 1 (2008), 1.

In 2003, the second year, they drilled 55 more wells. It was not until Devon had drilled these wells that the company was confident that it had the technology, process, and know-how to be able to economically employ this technology for large-scale shale gas production.[75]

The Need for Further Technology Development

There is an immense need for further technological development in order to assure U.S. energy security, as well as the economical production of shale gas. The best accounting that exists for this need is a report done by the National Petroleum Council Oil and Gas Study (NPC) from 2007 titled "The Impact of Technology on Costs and Gas Recovery." This study assesses the current state of unconventional gas technology as well as the areas where further technological development are needed. The report broke its findings up into three time spans and set specific technological thresholds that would be needed in order to guarantee adequate supply, keep prices low, and maximize domestic reserves. The three time periods are 2010, 2020, and 2030. A number of needed technological developments are given for each of these time frames. These technologies are given priority according to the level of research, development, and investment needed to achieve the needed innovation. The distinctions are incremental, accelerated, and breakthrough, with the more research intensive being the latter. The significance that each technology will have on shale gas production is broken into two categories: moderate and significant. Of the twelve technologies that the survey found highly significant for the future of U.S. shale gas production, nine were in need of accelerated research and development, while six were in need of incremental research and development. The findings of this survey highlight the need to improve existing technologies, such as improvements in seismic imaging, fracturing fluids, and horizontal drilling techniques and equipment. The study found that there is also

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[75] Yergin, *the Quest,* 328-29.

significant technological development needing to take place by 2020. Of the 13 technological innovations needed by 2020, 6 of them are in need of accelerated technological development and one breakthrough development: real time drilling sweet spot detection. The NPC states that while the technological needs for 2030 are somewhat harder to predict than for 2010 or 2020, there needs to be significant investment made in research and development. The study predicts that of the technologies that are needed, two out of five technologies require accelerated research. The study also stresses the need for accelerated research on currently unknown technologies.[76]

The most pressing technology needs may be those that will reduce the environmental impacts of hydraulic fracturing and horizontal drilling. This need was not foreseen by the NPC study in 2007. Recent concerns raised by environmentalists and the general public have made addressing these issues an essential component for ensuring continued shale gas extraction. While shale gas producers doubt that their fluids have done any harm, the firms have taken action to avoid prohibitive policy actions.[77] Firms are experimenting with different levels of additives, replacing questionable chemicals, and attempting to improve their drill casing. There have also been concerns about the environmental effects of hydraulic fracturing companies' use of large amounts of water. Companies foresaw this issue and have been attempting to develop a process that can effectively recycle and reuse water, but they have yet to find their desired level of success. This innovation will come at the cost of continued lab research and field experimentation.[78]

As the data show, the ability to produce shale gas at economic rates has only been enabled by considerable levels of technological innovation in extraction processes and

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[76] National Petroleum Council, "Topic Paper #29," 22-29.
[77] Ian Urbina, "A Tainted Water Well and Concern there May Be More," *New York Times,* August 3, 2011.
[78] Ian Urbina, "Wastewater Recycling No Cure All in Gas Process," *New York Times,* March 1, 2011.

capabilities. As the NPC report demonstrates, there also continues to be a need for technological innovation to improve recovery within existing fields, and to tap into harder-to-reach shale formations. If the hypothesis is correct, it should be expected that the need for high-cost technological innovation will push energy firms toward inter-firm cooperation. These needs will also create incentives for the Chinese and U.S. governments to cooperate.

High Costs of Innovation and Drilling

Independent companies have done much of the drilling and have accomplished much of the innovation in shale gas extraction. Independents usually operate on thin margins and a low cost base. This has allowed them to respond quickly to the rapidly changing dynamics within the shale gas exploration industry, but it also leaves them ill prepared to face the steep costs of technological research and development alone. These are costs that they continually have to pay to ensure production. These firms often operate in marginal and technologically difficult reserves with smaller returns than those often developed by majors.[79] The comparison of investments in exploration made by major producers and independent producers is evidence of this. In 2007 majors invested $49 billion in natural gas exploration, compared to the $77 billion invested by independents in the same year.[80] These differences are due to the nature of independent producers. It is estimated that independent firms invest 150 percent of their net income back into drilling operations. Considering that these companies are much smaller than their major counterparts, these differences are meaningful and profound and help explain the need for increasing cooperation between U.S. and Chinese firms, as well as between the U.S. and Chinese governments.

[79] Beckwith, "Hydraulic Fracturing," 36.
[80] Committee on Oversight and Government Reform, "Pathways to Energy Independence: Hydraulic Fracturing and other New Technologies," 112th Cong., 1st sess., 2011, 13.

An excellent example of the high cost of shale gas production is the experience of Devon Energy in its early work in the Barnett Shale formation. Devon Energy drilled sixty-two wells before it felt confident that it had the technology in place to extract and produce shale gas economically on a large scale. Considering that the average price of one exploratory well is $7.6 million and can cost as much as $15 million with a success rate of only around 40 percent, it is apparent that the costs of developments in exploration and production technologies are enormous.[81] Further evidence of the dramatic increase in costs is the increase in prices as independents have moved from extracting conventional gas to unconventional. In 1999, the average cost for drilling one foot was $100. In 2006, the cost of drilling one foot had dramatically increased to $600. In order for firms that produce shale gas to meet the costs of production and technological innovation, they must rely on inter-firm alliances and cooperation.[82]

Inter-firm Alliances and Shale Gas

The NPC study points out that there are no accurate estimates on the amount of money invested in research and development.[83] However, the NPC estimated through industry surveys that in the ten years leading up to 2007 the general trend in investment in shale gas had been downward, but had picked up during the year prior to the survey.[84] This pick-up in investment dollars in the year 2005-06 led to shale gas having a significant impact on energy markets in 2007-08.[85]

After 2006, investment in shale gas grew rapidly. The firms involved in shale gas exploration and production entered into joint ventures to explore and develop shale formations

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[81] Shively and Ferarre, *Today's Natural Gas Industry, 13.*
[82] House Committee, *Pathways to Energy Independence* , 13.
[83] The NPC study mentions that firms choose not to share this information.
[84] National Petroleum Council, "Topic Paper #29," 22-29.
[85] Yergin, *the Quest,* 328.

throughout the United States. These ventures included agreements between a number of U.S. and international firms. The reasons cited for these joint ventures within the industry are to share costs as well as reduce research and development redundancies. Another reason cited by those in the industry is that collaboration offsets the high costs of gaining experience. By entering into inter-firm alliances, firms are able to take advantage of skills already acquired by their partner. In 2010, mergers and acquisitions in the energy production sector - mainly consisting of limited partnerships – amounted to over $465 billion. This number represented 21 percent of all mergers and acquisitions in all sectors, and was 32 percent larger than the number for 2009. Although not all of these deals involved shale gas, this resource was a popular target for firms looking to expand their operations.[86]

U.S. and Chinese Inter-Firm Cooperation

In 2010, Chinese companies began to enter into inter-firm alliances with U.S. energy companies. The first deal between CNOOC and Chesapeake Energy was in 2010 and was worth $2.2 billion. The deal granted CNOOC a one-third stake in the Eagle-Ford shale formation in Southwest Texas. Chesapeake and CNOOC agreed that their goal for the Eagle-Ford formation was to increase the number of drilling rigs in operation from ten to forty. Conditions of the agreement included CNOOC agreeing to provide the capital and technical expertise for a significant portion of the expansion.[87]

CNOOC and Chesapeake followed this deal with another similar deal for shale acreage in Wyoming and Colorado in January 2011. Industry analysts thought that this deal was made primarily for technology collaboration and transfer. CNOOC sought to improve its ability to tap

[86] Robin Beckwith, "Hydraulic Fracturing," 36;" National Petroleum Council, "Topic Paper #29," 33-34; Thomas Kaplan and Chris B. Nichols, "Occidental Adds to its U.S. Oil Properties," *New York Times,* December 10, 2010.
[87] Chris V Nicholson, "Cnooc in $2.2 Billion With Chesapeake Energy," *New York Times,* October 11, 2010

into reserves of natural gas in China. The ability to do so will help supply China's rapidly increasing demand for energy resources. Chesapeake entered the deal looking to reduce its debt level, raise capital, and take advantage of technological collaboration.[88]

Chinese and American firms have made two other deals. In January 2012, Devon Energy announced that it would sell a share of its shale operations to Sinopec for $900 million in cash and $1.2 billion in future drilling costs. Devon Energy cited reasons for making the deal as the recovery of drilling and land acquisition costs, as well as reducing future capital commitments.[89] Chinese firms have also sought to purchase U.S. shale technology firms. The most noteworthy of these deals is the competition between CNOOC and Sinopec to purchase a one-third share in the hydraulic fracturing technology company Frac Tech Holdings. Frac Tech Holdings is a collaborative enterprise. It is owned jointly by Chesapeake Energy (30%) and the sovereign wealth funds of China and Abu Dhabi (70%). Chinese investment and U.S. firms' willingness to allow it are evidence of the desire for increased research and development.[90]

Why Chinese Investment

As mentioned above, there have been many mergers in the energy industry worldwide. The Chinese firms were especially active. For example, the three largest Chinese energy firms spent $24 billion in 2010 and $18.5 billion in 2011 to acquire stakes in foreign energy assets. A number of these partnerships were attempts to gain the shale gas extraction technology developed in the United States. Chinese companies have made these investments in an effort to

[88] Leslie Hook, "Cnooc Strikes Second US Shale Deal," *Financial Times,* January, 31, 2011.
[89] Azam Ahmed, "Sinopec and Total Continue Shale Gas Buying Spree," *New York Times,* January, 3 2012.
[90] Dinny McMahon and Chester Yung, "China's Bid in Fracking," *Wall Street Journal,* December, 16 2011.

acquire American firms' shale gas technology. Chinese firms desire this technology so that they can begin to extract gas from China's large shale reserves.[91]

The American energy companies that have made these deals with Chinese companies are independents. Independents need large amounts of capital to ensure current operations, continue exploration, and further development. Since independents often run operations on thin margins, they are in constant need of money. This has been especially true for the major players in shale gas production, Chesapeake and Devon Energy. Capital from western investors has been especially hard to acquire. This is due to the lingering effects of the 2008 recession, as well as lower gas prices in the United States.[92] China has a large amount of capital and considerable incentives beyond profit to continue investing in shale assets. This is due to a number of factors. China has been the beneficiary of a large trade surplus with the United States which has allowed it to accumulate hundreds of billions of dollars. For example, in 2010 it held $2.5 trillion in foreign currency. This has permitted the Chinese government to make large loans on favorable terms to its energy firms. These loans allow China to invest its large cash reserves in more tangible energy assets.[93]More importantly, however, investment in U.S. shale gas producers has the added benefit of further securing Chinese future energy security. China has an estimated 1,275 tfc of technically recoverable shale gas within its national borders. Because of this incentive Chinese companies have continued to invest in U.S. shale gas resources, even though

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[91] Dinny McMahon and Chester Yung, "China's Bid in Fracking," *Wall Street Journal,* Dec 16, 2011 and Leslie Hook, "Cnooc Strikes Second U.S. Shale Deal," *Financial Times* Jan 31, 2011 and Robert M. Cutler, "China Shale Drive Appears Over Ambitious," *Asia Times Online* Feb 18, 2012.
[92] Sui Lee Wee and Anna Driver, "China's Cnooc tests U.S. with Chesapeake Shale Deal," *Reuters,* Oct 11, 2010.
[93] Cyrus Sanati,"Stockpile of Dollars Drives China's Energy Strategy," *New York Times,* Oct 1, 2010.

natural gas prices have been low. This investment by Chinese firms, however, is just as much, if not more, about technology transfer as it is about profits.[94]

U.S. Political Reaction to Chinese Investment and Cooperation

U.S. policy makers' reactions to Chinese firms' involvement in U.S domestic shale gas production have largely been positive. There is general recognition that in order for the United States to ensure energy security it must invite investment that pushes technological innovation forward, as well as reducing Chinese demand for foreign energy products. Policy makers have acknowledged that this is best done by helping China obtain the required technology to tap into its own large domestic reserves.[95]

This enthusiasm has led the United States to cooperate with China on a number of fronts in the hope of increased production and reduced resource competition. In 2007, the United States Trade and Development Agency began instruction of a class that brings Chinese and U.S. energy professionals together. The stated purpose of the course was to "strengthen industry cooperation and technical collaboration between U.S. and China government and private sector entities in the area of natural gas development."[96] In 2009, U.S. President Barrack Obama and Chinese president Hu Jintao also initiated the U.S.-China Shale Gas Resource Initiative. The goal of this initiative is to share shale gas technology, collaborate on future technology projects, and open up

[94] USCC, "Testimony of Sarah M. Forbes," *Hearing Before the U.S.-China Economic and Security Review Commission "China's Global Quest for Resources and Implications for the United States; China's Prospects for Shale Gas and the Implications for the U.S.,"* (January 26, 2012): 84-86.
[95] The White House, "Fact Sheet: U.S.-China Shale Gas Resource Initiative," (November 17, 2009).
[96] United States Trade and Development Agency, "U.S. Natural Gas Training Program Catalog 2007-2009: Focusing on Upstream, Midstream and Downstream," *U.S. Trade and Development Agency Training Catalog.*

both countries for mutual shale gas investment.[97] This is further evidence of policy makers' recognition of the importance of Chinese investment and technological collaboration.

Washington was almost entirely silent about the three shale gas deals made between Chinese and U.S. companies. Policy makers have yet to raise concerns about the threat posed by Chinese shale gas investment. Tellingly, before the Eagle Ford Shale venture between CNOOC and Chesapeake in 2010, the Committee on Foreign Investment in the United States precleared the deal.[98] The two other joint ventures entered into by Chinese and American companies received similar treatment. There has likewise been nothing said about two Chinese companies being the only bidders for a one-third share of a U.S. shale gas technology company. Policy makers have remained silent because Chinese firms' investments promise to improve U.S. energy security.

Increasing cooperation between the United States and China provides support for the hypothesis. U.S. policy makers have been open to investment from Chinese companies since the benefits of allowing investment significantly outweigh the costs. Allowing for Chinese investment and technological collaboration on domestic projects is the best way for policy makers to secure adequate energy supplies. This is true for a number of reasons. By not allowing Chinese capital, policy makers would be cutting off U.S. energy firms from opportunities for technological collaboration, as well as limiting opportunities for capital acquisition. This would limit the ability of most energy producing firms to start new projects and extract more technologically difficult shale resources. If these firms were unable to undertake these activities, it would jeopardize U.S. energy security. The U.S. would have the assets in the ground but

[97] The White House, "Fact Sheet;" USCC, "Testimony of Sarah M. Forbes, 114-116."

[98] Chris V. Nicholson, "China's Energy Industry Pushes into Developed Markets," *New York Times,* March 14, 2011.

would not be able to extract them economically and bring them to market. This would force the United States to aggressively seek less reliable imports from foreign energy producers and would decrease energy security.

Conclusion

After introducing the independent variables of the hypothesis, the need for high levels of technological development and capital offer a compelling explanation for the change in U.S. policy toward Chinese energy investment from 2005 to the present. This helps support the hypothesis that this research set out to test: For an energy project, if technological intensity and capital intensity are high, it is likely U.S. policy makers will support cooperation and allow for foreign investment.

According to the findings of this research, Chinese investment and U.S. energy producers capital requirements can be expected to grow as energy firms move from the more easily accessible shale formations to more difficult ones. This investment is also most likely to continue to come from China. Chinese companies have more to gain than any other investor since such collaboration has the potential to help them develop their own substantial energy assets. Since Chinese firms have motives beyond profit making they are more likely than other firms to continue investment in the face of low prices. As natural gas continues to be developed, it has had the effect of depressing the market price since supply has exceeded domestic demand. U.S. policy makers can be expected to continue to allow investment to the point that it offers the potential for further energy security.

The findings of this research and the implications of the hypothesis are somewhat limited in the scope of applicability to cases not directly related to the United States and China. There are few other states with both the capability to aggressively seek energy resources and the need to do so. For the United States and China resource extraction is a zero-sum game. Both countries have, and continue to face, large energy deficits. Other countries that face comparable deficits do not have energy firms within their borders with the capital or technological knowledge to aggressively seek foreign resource assets. These findings are also limited in their ability to continue to predict U.S. policy makers' behavior if large scale LNG exporting capabilities are built in the United States. Under this scenario, the incentives for policy makers change, but the response should continue to be towards openness to Chinese investment to the point that the energy security gained through Chinese investment significantly outweighs the loss from exported LNG.

There is a significant need for further research using this model. If the hypothesis is correct, it should be able to explain and predict current and future U.S.-Chinese energy cooperation in other energy projects that have high entry costs and the need for significant technological development for long-term economic extraction. Further research will need to look at other unconventional resource extraction methods such off shore drilling, coal gasification, and shale oil exploration. Since each of these three methods of resource extraction has high entry costs and requires significant amounts of technology, based on the findings outlined by this research, it should be expected that these areas of fossil fuel exploration should encourage cooperation.

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