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BRICS Built with STIPs

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The role of Science, Technology and Innovation Policy in the economic development strategies of contemporary China, Brazil and South Africa.

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Abstract

In 2014 Brazil, Russia, India, China and South Africa (BRICS), ratified the "Cape Town Declaration," which recognized the "paramount importance of science, technology and innovation (STI) for human development." This declaration not only represents the growing importance of STI policy just in the BRICS states, but highlights the emergence of STI as a precondition of modern economic growth. This paper examines the significance of state STI policy as an increasingly important facet of strategic economic and state development in today's globalizing world. Additionally, this paper offers a comparative analysis of STI strategies in three BRICS countries. The research supports two major conclusions. First, in today's globalizing world, the capacity of the state, and implementation of effective STI policies, both play fundamental roles in enabling economic growth in developing countries. Second, a comparative analysis of BRICS STI policies provides empirical examples of how specific strategies can effectively, or ineffectively, contribute to economic growth and overall state development. In this comparative analysis, it is clear that despite each country's commitment and intent to build STI capacity, historical and political context are influential in determining the successful implementation of effective STI policy in any given country.

Introduction

On February 10th, 2014, science and technology representatives of Brazil, Russia, India, China, and South Africa (BRICS) met in Cape Town. This gathering marked the first BRICS Science, Technology and Innovation (STI) Ministerial Meeting and the ratification of the "Cape Town Declaration." The declaration is one of the first of its kind, specifically designed to recognize the importance of STI within development. It reads:

> "We stress the paramount importance of science, technology and innovation for human development, while recognizing the role and significance of competitiveness in the rapid technologically changing global environment, we agree that public driven science, technology and innovation supporting equitable growth shall form the basis of our cooperation."[1]

In many ways, the Cape Town Declaration reflects the nature of state development strategies in the post-industrial era. However, the rise of STI policy to the forefront of state growth did not happen overnight. In their 1988 discussion of the "catching up" process for developing countries, Carlota Perez and Luc Soete, famously hypothesized that "windows of opportunity" for new industries are, in large part, facilitated by the development of public science.[2] This perception, that science can be a catalyst for economic growth, is a theory that has grown dramatically. Today, many scholars agree that science is no longer a luxury for less-developed countries, but an important precondition for contemporary economic development.[3] [4] [5]

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[1] DST, Department of Science and Technology. *Innovation Towards a Knowledge Based Economy Ten-Year Plan for South Africa*. 2007.

[2] Soete, Luc. "2 1 Catching up in technology: entry barriers and Windows of opportunity." 1988.

[3] Bernardes, Américo Tristão, and Eduardo Da Motta E Albuquerque. "Cross-over, thresholds,

Developing countries like China, India, Brazil, South Korea, Russia and South Korea have all integrated transformative STI strategies into state policy in the past two decades. At a time when many perceive the state to play a less significant role in development, why is STI policy becoming increasingly important amongst these emerging countries? Additionally, how do states hope to create growth and competitiveness by developing STI?

This paper analyzes the role of STI policies in state development within several BRICS countries (China, Brazil and South Africa). Specifically, it asks how, if at all, certain STI policies make these states more globally competitive and/or enable them to foster economic growth and why states believe STI is crucial to development. This research investigates the role of the state in modern development, especially its use of STI policy. Additionally, the paper offers comparative case studies of three modern STI policy strategies, all of which are being implemented in the development strategies of emerging countries.

This research supports two major conclusions. First, despite various political and historical contexts, many developing countries have prioritized economic growth as the primary engine of development. However, how states obtain this economic growth has changed. In the age of globalization, developing states are fighting to remain competitive, grappling for footloose capital, and striving to integrate themselves into a global economy. It is apparent that the development of STI capacity and its integration into domestic industries is now an effective way

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and interactions between science and technology: lessons for less-developed countries." *Research Policy* 32, no. 5

[4] Lundvall, Bengt-Åke. *National systems of innovation: toward a theory of innovation and interactive learning*. London: Anthem Press, 1992.

[5] Freeman, Chris. "The 'National System of Innovation' in historical perspective." *Cambridge Journal of Economics* 19, no. 11 (1995)

for developing states to do this. Consequently, in today's world the organization and implementation of effective STI policies play a fundamental role in enabling economic growth in developing countries.

Second, an analysis of contemporary Chinese, Brazilian and South African STI policy reveals that all of these states recognize the aforementioned importance of developing STI capacity. Each state, emerging from its specific historical patterns of development has come to embrace STI growth as a cornerstone of its modern development: China, from a rigid socialist background, Brazil emerging from a history of authoritarian developmentalism and South Africa, recovering from apartheid and a divided past. All of these states are now implementing strategic STI policies. These states have prioritized global economic growth and positioning, and now perceive STI development as a gateway to achieving this within a globalizing economy. However, despite their intent to boost economic growth and state development with STI advancement, historical and political contexts present unique challenges in each case. We find that the *successful* development and integration of STI within a state's economy can result in significant economic growth and overall societal progress. However, *unsuccessful,* or inefficient development and integration of STI in some areas can result in stunted economic growth and can limit societal growth. The limited capacity of the state to develop or implement policy, a lack of financial support of STI, or an inability to integrate innovation within existing industry, can all hinder STI growth.

These findings are presented in two sections, each with several subsections. The first half of the paper analyzes the shifting economic realities of the international community, the role of

state within this community, and why STI policy is now understood as such a fundamental piece of state development (economic and otherwise). In the past 40 years our world has changed dramatically. In the age of globalization, a debate has emerged concerning the role of the state. As STI policies are the product of the state, we must seek to understand how the changing role of the state affects state policy and intervention. This section is divided into four focused areas. First it offers a discussion of globalization and the role of the nation state in today's world. Second and third it engages the concepts of the developmental state and the competition state respectively. Together, these theories effectively frame the role of the state today, especially in developing countries hoping to find economic growth as a result of implementing various STI policies. Fourth, we will focus attention on STI, what it is, and why it is so important to these states today.

The second major portion of this paper offers a comparative analysis of China, Brazil and South Africa's respective modern STI policies, the historical and political context in which they are constructed, and finally how effective they are as a facet of larger development strategies. This portion of the paper begins with a brief explanation of the significance of the STI areas analyzed in each country, and describes how STI output and capacity can be measured. These individual case studies provide empirical examples of how effectively or ineffectively STI can influence economic and state development. This half of the paper is divided into three major sections, each of which addresses a developing state's modern STI plan. First is China's Medium to Long-Term Plan for the Development of Science and Technology. Second is Brazil's Greater Brazil Plan, and last is South Africa's Ten-Year Plan of Innovation Towards a Knowledge-Based

Economy. Each section provides a contextual background, a measurement of science and research, and an analysies of innovative capacity and integration (this is discussed further in the methodology section). Finally, the paper concludes with a discussion of the implications of this research.

Globalization, and the Role of the State

Globalization is a term often used to describe the nature of the international community today. In many ways, we find that globalization has shaped the environment in which emerging powers (like the BRICS) now hope to operate, and compete. There is no denying that the international community has shifted dramatically in the past 40 years. These developments have contributed to the creation of an international community that is subject to the increasingly rapid migration of people, money and ideals on a massive scale. In their introductory text to the subject, *Globalization: A Basic Text,* George Ritzer and Paul Dean define globalization as the following:

> "Globalization is the transplanetary process or set of processes involving increasing liquidity and the growing multidirectional flows of people, objects, places and information as well as the structures they encounter and create that are barriers to, or expedite, those flows."[6]

Few contest the existence of globalization, but the implications and extent of globalization are the subject of much debate. At the heart of this debate is the role of the state. The rise of these "multidirectional flows" calls into question whether the significance of the nation state has been weakened. Some believe that globalization marks the end of the nation state

[6] Ritzer, George, and Paul Dean. *Globalization: a basic text*. Oxford: Wiley-Blackwell, 2015, 2.

as the primary building block of the international community, and the demise of the national economy.[7] [8] [9]Additionally, many theorize that globalization has and will continue to change how we understand economic growth. In his book *The End of the Nation State: The Rise of Regional Economics,* Kenichi Ohmae states that "genuinely global capital markets dwarf [the state's] ability to control exchange rates or protect their currency."[10] He goes on to assert that nation states are now "remarkably inefficient engines of wealth distribution."[11] Clearly, globalization has radically impacted the ability of the nation state to achieve economic development. While a world *not* dictated by the actions of a collection of nation states is difficult to imagine, the effect that globalization has had on the global economy, and state development, is significant. Consequently, we must seek to understand the role of the nation state in a different light than we have in the past.

Theorists who do not perceive globalization to be the end of the nation state have presented a number of theories as to how the role of the nation state in the modern economy has *changed* in response to this phenomenon. These scholars suggest that in light of globalization, the state is not destined to crumble, but to simply shift or evolve.[12] In some cases, theorists claim that globalization has even caused an increase in state intervention and influence. These theories

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[7] Reich, Robert. "The work of nations: Preparing ourselves for twenty-first century capitalism." *New York: Alfred Knopf* (1991).
[8]Ohmae, Kenichi. *The end of the nation state: the rise of regional economies*. New York: Free, 2010.
[9]Waters, Malcolm. "globalization Routledge." *London and New York* 94 (1995): 123-157.
[10] Ohmae, Kenichi. *The end of the nation state: the rise of regional economies*. New York: Free, 2010, 12.
[11] Ibid.
[12] Ibid.

address how states might behave in order to continue building a growth-oriented national economy, despite the effects of globalization. Several of these contribute a theoretical framework that helps explain the role of STI policy amongst emerging states. Most importantly, they explain *how* it is that the state continues to be influential in sparking economic growth and development.

The Developmental State

The developmental state theory, while not a concept that emerged directly in response to globalization, provides an example of how the increased role of the state can influence economic growth and state development. This is an excellent starting point from which we can begin to understand how the state, despite globalization, continues to play a fundamental role in economic growth. Initially conceptualized by Chalmers Johnson in light of what he calls the "Japanese Miracle," a developmental state is characterized by certain types of macroeconomic strategy and state intervention. In his book *MITI and the Japanese Miracle,* Johnson identifies certain methods used by the Japanese government, specifically by the Ministry of International Trade and Industry (MITI), that sparked unprecedented economic growth. Johnson lists strong state intervention, planning, and regulation as major factors that contributed to this massive growth. The author observes that "in states that were late to industrialize, the state itself led the industrialization drive."[13] In this way states "[take] on developmental functions." Developmental states prioritize economic growth through strategic industrial development and find ways to influence growth in any number of ways. In the case of Japan, Johnson claims that the strict

[13] Johnson, Chalmers A. *MITI and the Japanese miracle: the growth of industrial policy: 1925-1975*. Stanford: Stanford University Press, 2012, 19.

bureaucratic guidance of Japan's largely privately owned industry led to the "Japanese miracle."[14] The developmental state model, especially in Japan, is dependent on the relationship between state bureaucracy and privately owned business. Cooperation and regulation are both integral parts of managing this relationship.[15]

In the book, *The Developmental State,* edited by Meredith Woo-Cumings, Johnson comments on the *MITI* text, affirming that states will only be able to recreate the growth observed in Japan if a "nation is similarly committed to the mobilization of industry."[16] The majority of developmental theorists have cited the prioritization of economic growth as the most important characteristic of the developmental state.[17] [18] Time has shown that a number of states have made this commitment. Many observers have identified South Korea, Taiwan, Singapore Hong Kong, China, and Thailand as developmental states.[19] Furthermore, the "developmental state" is now a term used to describe governments that strive to intervene in economic processes in an attempt to direct the course of development, as opposed to just relying merely on market forces.[20] Consequently, nations have been labeled developmental states not only in Asia but in

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[14] Johnson, Chalmers A. *MITI,*12.
[15] Ibid.
[16] Woo-Cumings, Meredith. *The developmental state*. Ithaca (N.Y.): Cornell university press, 1999, 41.
[17] Amsden, Alice H. *Asia's next giant: South Korea and late industrialization*. New York: Oxford University Press, 1992.
[18] Öniş, Ziya. "The Logic of the Developmental State." *Comparative Politics* 24, no. 1 (1991): 109-26.
[19] Woo-Cumings, Meredith. *The developmental state*. 1999, 40.
[20] Stubbs, Richard. "What ever happened to the East Asian Developmental State? The unfolding debate." *The Pacific Review* 22, no. 1 (2009).

Europe and Latin America as well.[21] [22]

The developmental state theory provides insight into the importance of economic growth in overall state development. The BRICS countries examined in this paper share many of the characteristics of these developmental states. As we will discuss later, the BRICS states have undoubtedly prioritized specifically targeted economic growth strategies, in the hopes that they will lead to social development. Thus, the developmental state theory is one way to understand how the influence of the state may still be important today. These scholars surmise that direct state influence can create rapid economic growth and ensuing development. It is through this perspective of that state intervention may be understood to be even more important to developing nations today than it has been in the past. While it is clear that globalization has impacted how states interact with the international economy, this theory would suggest that a state's capacity to implement strategic macro-economic policy is *integral* to national economic development. However, it is important to understand how the type of economic growth pursued has changed in light of globalization. The concept of the competition state explains how the prioritization of economic growth contributes to development in the post-industrial era.

The Competition State

The second theory that is useful in developing our understanding of the state's role in development today is that of the competition state. While the developmental state describes the

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[21] Ricz, Judit. "Developmental State in Brazil: past present and future." *Federalismi.it*, October 29, 2014, 2-20.
[22] Williams, Michelle. *End of the developmental state?* Place of publication not identified: Routledge, 2015.

importance of state-driven economic growth strategies especially in an age of industrialization, the competition state contributes to our understanding of how states seek growth in a post-industrial age. This theory is famously described by Philip Cerny. "Paradoxes of the Competition State: The Dynamics of Political Globalization." Cerny argues that globalization has left states "seeking to adapt to a range of complex changes in cultural, institutional and market structures, [as] both state and market actors are attempting to reinvent the state."[23] It is important to note that Cerny does not contest globalization itself, but examines how the role of the state has changed in light of globalization. He argues that globalization "does not lead to a simple decline of the state but may be seen to necessitate the actual expansion of de facto state intervention and regulation in the name of competitiveness and marketization."[24] Here, Cerny argues that the inability of states to "insulate" their national economies from the global economy has resulted in the rise of what he calls the competition state. Within the context of this research, it is useful to understand China, Brazil and South Africa as competition states. The author describes how these competition states do not remove national economic activities that are hindered by globalization, but simply find ways to make these "economic activities located within the national territory more competitive in international and transnational terms."[25] This concept of the competition state provides an explanation as to why the influence of the state would be more, rather than less, significant in the economic development of emerging powers.

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[23]Cerny, Philip G. "Paradoxes of the Competition State: The Dynamics of Political Globalization." *Government and Opposition* 32, no. 02 (1997), 1.
[24] Ibid.
[25] Ibid., 259.

More importantly, Cerny's competition state concept contributes to our understanding of the purpose of STI policy amongst emerging powers. The development of STI and STI policy in emerging powers (like the BRICS) can, and should, be understood as part of a larger strategy to make national economic strategies more competitive in a global context. As we have discussed, globalization has called into question the viability of the nation state, and the role of the nation state in the modern world economy. Cerny shows us that the "nation state, of course, is not dead, but that its role has changed."[26] STI policies are one of the many ways that state influence contributes to the economic development of any nation. In the cases of China, Brazil and South Africa, we can see that their STI policies reflect this desire to be competitive in the global economy.

In this paper, we will investigate how STI policy is utilized by states to create economic growth. Specifically, we consider why certain policies are advantageous to specific states. Both of the aforementioned theoretical frameworks are useful in understanding the role of the state and a state's STI policy in developing economic growth. The states analyzed in this paper can be understood as quasi-developmental states, that now utilize STI growth as a tool to build domestic economies that make the state competitive in global markets. In this case, it is clear that the role of the state remains critical to ensure economic growth in developing countries.

As a part of the BRICS group, China, Brazil and South Africa are uniquely positioned in the world economy to display the role of the state and STI policy in economic development.

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[26] Cerny, Philip G. Competition State, 269.

What and Why? Analyzing the BRICS

The BRICS states are all nations that have identified strategic economic growth as their foremost priority, and the driving force behind their own development. Similar to Johnson's developmental states in Asia, these states have constructed policies that have become a catalyst for achieving economic development. This reliance on industrial and economic growth to spark development make the BRICS excellent candidates for this research.

The BRICS group is a family of five emerging powers that have all observed rapid economic growth over the past several decades. In 2001 Global economist Jim O'Neill labeled Brazil, Russia, India, and China as the BRIC group. In his report entitled *Building Better Economic BRICs,* O'Neill predicted that in the coming years these states would soon account for nearly 25% of the world's GDP.[27] Their "significant development opportunities" and emergence into the international community is what characterizes the BRICS.[28] In an article addressing the rise of BRICS countries, Chan-Yuan Wong and Lili Wang write, "despite their various populations, sizes, and natural layouts and resources one important common characteristic of these countries is that they are all marked by dynamic and promising economic growth and have affirmed commitments in pursuing science and technology."[29] Since their classification in 2001, many emerging countries have expressed interest in being included within the group of four

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[27] O'Neill, Jim. *Building better global economic BRICs*. New York: Goldman, Sachs & Co., 2001, 1.

[28] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives: innovation systems and policies*. London: Anthem, 2011, 1.

[29] Wong, Chan-Yuan, and Lili Wang. "Trajectories of science and technology and their co-evolution in BRICS: Insights from publication and patent analysis." *Journal of Informetrics* 9, no. 1 (2015): 90-101., 1.

states initially identified by O'Neill. In 2010 South Africa was invited to join the group, which became known as the BRICS. While South Africa is undoubtedly the most underdeveloped economically of the group, its growth is comparable to the other BRICS. The BRICS countries have clearly established themselves within the international community as states pursuing rapid and competitive economic growth on a global scale.

Of course, the significance of the BRICS as well as their ability to affect change in the international community is the subject of much debate. Some perceive the rise of BRICS countries as the beginning of a power transition from a unipolar to a bi-or multipolar world.[30] However, others believe that "straight line" projections of rapid BRICS growth are misleading. Regardless, there is little debate over the potential growth and economic integration of BRICS states. In their book *Emerging Economies and the Transformation of International Business,* Dominic Wilson and Roopa Purshothaman suggest that in the next 50 year the BRICS economies could "become a much larger force in the world economy."[31] Wilson and Purshothaman surmise that the BRICS must be understood as an "engine of new demand growth and spending power."[32] The actions of the BRICS carry significant weight and clearly have the potential to effect change. Additionally, their policy and development strategies represent how emerging powers are attempting to modernize and remain competitive. The BRICS states are obvious candidates for furthering our understanding of STI's role in modern state development.

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[30] Glosny, Michael A. "China and the BRICs: A Real (but Limited) Partnership in a Unipolar World." *Polity* 42, no. 1 (2010): 100-29. doi:10.1057/pol.2009.14.
[31] Jain, Shuhash C. *Emerging economies and the transformation of international business: Brazil, Russia, India and China (BRICs)*. Cheltenham: Elgar, 2006, 3.
[32] Ibid., 4.

These countries are poised for massive growth and constantly jostling for international standing. Consequently, how these states create and implement policy is an apt reflection how states are attempting to foster economic growth today. As O'Neill's report and others like it have shown, the BRICS represent roughly half of the world's population and almost a quarter of the world's GDP.[33] It is these states' growth and growing economic clout that makes them of great interest for those seeking to better understand modern international development. *How* these states compete with one another, and how they integrate themselves into global markets, is a reflection of what emerging powers are doing to remain competitive today. As Cerny discusses in *Paradoxes of the Competition State,* the behavior of the BRICS is simply an example of how states have adjusted or evolved to remain globally competitive.

This paper analyzes STI policy and interest in Brazil, China, and South Africa. However, this paper does not investigate the role of STI in all five BRICS countries. The three countries examined in this paper have been selected in a strategic manner to represent the diversity amongst the BRICS states, both in economic means, as well as STI growth. China represents the largest economy, as well as the BRICS country with the largest population. Additionally, China represents the most advanced state within the BRICS in terms of STI capacity. Brazil represents the middle of the economic spectrum, with a GDP similar to that of India. While its STI growth has not been as rapid as China's, Brazil has shown some growth and represents the median of BRICS STI capacity. South Africa is by far the most economically challenged of the group, and has observed the least STI growth in recent years. These three states represent the diversity

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[33] O'Neill, Jim. *Building better global economic BRICS*, 4.

within the BRICS groups and the varying levels of STI capacity within these emerging regions.

STI and STI Policy

Countries utilize a wide variety of strategies and policies to secure economic growth and state development. Furthermore, STI-related policies are not the only strategies that can be understood as an indicator of modern international development. Nevertheless, STI plays an increasingly significant role in the development of BRICS states and other emerging countries. Both the changing and growing influence of STI policy within development strategy make it a promising indicator of modern state development, as is evident in the creation of the Cape Town Declaration. Therefore it is important that we understand the impact of STI on development today. Our exploration of Brazil, China, and South Africa's STI policy will call upon existing literature that engages the rise of STI policy, while contributing an insight into how STI policy can influence state development today.

"Economists have known for decades (and suspected for centuries) that intangibles such as ideas, knowledge, technology, and scientific discoveries drive the process of growth."[34] Economist Paul Romer's words are an apt description of the economic realities we understand today. Just as the role of the nation state has changed in response to globalization, so have the strategies used by states to achieve economic growth. In what some call the "information age" or the "knowledge economy," economic growth is now understood to be driven by knowledge and the accessibility of said knowledge. It is no longer labor that "drives long-run economic

[34] Jaffe, Adam B., and Manuel Trajtenberg. *Patents, citations and innovations: a window on the knowledge economy*. Cambridge, MA: MIT, 2005, 1.

performance" but this knowledge cultivated within the state.[35]

Many analysts believe that STI policy in emerging powers, and especially BRICS states have undergone a "radical transformation over the last couple of decades."[36] It is this restructuring of STI policy that is especially of interest to this analysis of modern development trends. At the core of this restructuring is the development of what scholars refer to as national systems of innovation (NSIs). In a collective analysis compiled by a number of scholars, *Development Alternatives: Innovation Systems and Policies,* these innovation systems are defined as the "industrial, science and technology, and educations subsystems, [including] the promotion, financial and regulation subsystem, as well as other spheres connected to the national and international contexts where knowledge is generated, used and diffused."[37] Scholars believe that the development of an NSI has now become the engine of capitalist growth.[38] [39]

Of course, developing and implementing innovation comes in many forms. Regardless of how states foster innovative growth, the social act of learning lies at the heart of innovation. Economist Bengt-Ake Lundvall, whose work is primarily organized around innovations systems issues, claims that any NSI relies on a "dynamic system" that is characterized both by obtaining

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[35]Jaffe, Adam B., and Manuel Trajtenberg. *Patents, citations and innovations: a window on the knowledge economy*. Cambridge, MA: MIT, 2005,

[36] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives: innovation systems and policies*. London: Anthem, 2011, 1.

[37] Ibid., 2.

[38] Nelson, Richard R. *National innovation systems: a comparative analysis*. New York (N.Y.): Oxford University Press, 1993.

[39] Fagerberg, Jan. "Technology and international differences in growth rates." *Journal of economic Literature* 32, no. 3 (1994): 1147-1175.

and by reproducing knowledge.[40] At the core of any NSI is the ability of a country to develop knowledge that is accessible to the larger population and industries. Any state hoping to build a strong NSI must first create a culture of learning and innovation. States achieve this type of STI development in a number of different ways. At the core of all such strategies lies the development of scientific and technological capacity through strategic knowledge acquisition.

Regardless of *how* states pursue innovative growth, the importance of this innovation should not be overlooked. This research engages what policies are used to develop NSIs because of their perceived importance amongst emerging countries. History, and existing literature show us that the influence of innovation systems in economic development is significant. In his 1995 article, *The "National System of Innovation" in Historical Perspective,* renowned English economist Chriss Freeman states that "national and regional systems of innovation remain an essential domain of economic analysis."[41] Freeman recognizes that despite the increasing importance of "international connections," systems of innovation are both "fundamental" and "necessary" to the economic development of any country.[42] The importance of NSI development is clearly critical to the overall economic advancement of any state. These features of innovation make it a useful indicator of a state's economic promise.

This paper will examine what types of policy BRICS use to further their own systems of innovation, as well as how these policies are indicative of current international trends. STI policy

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[40] Lundvall, Bengt-Åke. *National systems of innovation: toward a theory of innovation and interactive learning*. London: Anthem Press, 1992, 2.
[41] Freeman, Chris. "The 'National System of Innovation' in historical perspective." *Cambridge Journal of Economics* 19, no. 11 (1995): 5-24.
[42] Freeman, Chris. "The 'National System of Innovation' (1995): 5-24., 1.

takes many forms and must be considered within the "specific systemic context in which a national government intervenes."[43] Additionally, states must constantly tweak their STI policies to adapt to a world that is "characterised by a radical shift in techno-economic foundations."[44] This makes STI policy an excellent reflection of modern development strategies, and clearly indicates that STI is now a crucial driver of modernization. In his book *National systems of innovation: Toward a Theory of Innovation and Learning,* Lundvall states that to achieve sustainable economic growth countries must "cope, successfully, with change and exploit new technical opportunities"[45] In this way STI policy represents a critical facet of modern economic growth and national development.

Methodology and Analysis

As we have previously discussed, the BRICS states have prioritized economic growth as a primary driver of development. Consequently, the policies that these states utilize to achieve economic growth are especially of interest. In this paper we will analyze the role of STI policy in Brazil, China and South Africa focusing specifically on how these state's strategies influence economic growth. How these countries shape their STI strategies is dependent on various factors, such as infrastructural capacity, political realities, and historical context. These states use a variety of methods to spur domestic economic growth and attract foreign capital. However, scholars and politicians alike recognize the development of several fields as fundamental to the

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[43] Lundvall, Bengt-Åke. *National systems of innovation.* (1992). 6
[44] Ibid., 5.
[45] Ibid., 5.

growth of STI. Two fields that are identified in essential NSI literature[46] [47] [48] as core to the development of STI capacity. These texts recognize a division between the production of science and the production of technology. In accordance with this perspective, each individual state analysis will examine both the institutions and firms that produce science, as well as those that produce technology.

In our investigation of BRICS STI policies, we will first analyze how each state influences the capacity of universities and research institutions. Generally speaking, NSI scholars believe that these institutes are hubs of research that produce science, and necessary basic research. For innovation to occur, research is an absolutely essential feature of any NSI. Furthermore, some scholars stress that these organizations play a critical role in developing a culture of innovation within a state.[49] For this reason, the funds a state devotes to research and development (R&D) relative to their GDP is often used to measure a state's commitment to STI development. While there are private firms that do contribute to the development of basic research, universities and research institutions are generally considered to be the primary drivers of research. Additionally, the capacity of universities to produce knowledge workers is critical to the development of any strong NSI. Publication data will be used to measure the ability of each country's STI policy to develop research capacity. The number of research works published

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[46] Nelson, Richard R. *National innovation systems: a comparative analysis*. New York (N.Y.): Oxford University Press, 1993.
[47] Freeman, Chris. "The 'National System of Innovation' in historical perspective." *Cambridge Journal of Economics* 19, no. 11 (1995): 5-24
[48] Lundvall, Bengt-Åke. *National systems of innovation: toward a theory of innovation and interactive learning*. London: Anthem Press, 1992.
[49] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives: innovation systems and policies*. London: Anthem, 2011.

within a given period provides a baseline of the productivity of a state's universities and research institutions. Citation rates of a nation's publications will also be utilized to measure the quality of each state's research. Additionally, these figures play a crucial role in incentivising foreign scientific investment. Strong publication and citation numbers show that a state is a hub of R&D.

Secondly, we will examine firms (private and state-owned) that develop new technology. Again, there are universities that contribute to the diffusion and development of knowledge, but NSI literature emphasizes that the "main technological labor division involves this basic division"[50] of organizations that produce science and those that produce technology. Thus, for our purposes, we will examine firms as the primary drivers of innovation. For state STI policy to effectively develop innovation, original scientific research must be present and applicable for firms to develop new technologies. This integration of knowledge and knowledge workers with firms that advance technology is a critical piece of developing innovation capacity. States can encourage the development and integration of new technology into state industry in many ways. By offering tax incentives, grants, or government resources to innovation firms, these countries can spark the development of technology. Innovation capacity will be measured primarily through patent statistics. Patents awarded within a given time period serve as a key indicator of innovative activity within a country. Additionally, patent applications by domestic and foreign firms within any given country are also useful indicators of which sectors are technologically active. Like publication figures, patent statistics serve as an indicator of the technological environment of a given state to foreign investors. Strong figures emerge from countries with a

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[50] Bernardes, Américo Tristão, and Eduardo Da Motta E Albuquerque. "Cross-over, thresholds, and interactions between science and technology. (2003). 886.

strong culture of innovation and development.

Additionally, NSI's and STI policy are not only defined by these two areas, but by how they interact, and how new technologies are integrated within state industry. Of course, growth in science and technology alone will not necessarily drive economic growth. These sectors must interact, and produce innovative solutions for state industries. Without this interaction, STI development can hinder economic growth and state development. The second section of this paper will analyze the context of STI within each state, how state policy influences the two aforementioned areas, as well as the ways that these institutions interact. In doing this, we will establish a practical understanding of the role of STI policy plays in the development of Brazil, China, and South Africa.

China

At a major S&T conference in 2016, Chinese President Xi Jinping made the goals, and intent of Chinese STI policy very clear. Xi stated that China would surely establish itself as one of the "most innovative countries by 2020 and a leading innovator by 2030, before realizing the objective of becoming a world-leading S&T power by the centenary anniversary of the founding of the People's Republic of China in 2049."[51] At the convention, President Xi also stressed the importance of of STI. "S&T are the bedrock upon which the country relies for its power, enterprises rely for success, and people rely for a better life;" Xi went on to say that "Great scientific and technological capacity is a must for China to be strong and for people's lives to

[51] "Xi sets targets for China's science, technology mastery." China Association for Science and Technology. Accessed April 16, 2017.

improve."[52] Like the STI and NSI the scholars we discussed previously, China has identified STI growth as an essential piece of economic and societal development. China's 15 year, "Medium- to long-term plan for the Development of Science and Technology" (MLP) describes China's aggressive strategy to become a "world leader in S&T by 2050."[53]

However, STI policy and strategy have not always been at the forefront of Chinese development strategy. Similar to many other transition states, STI has played an increasingly significant role in these strategies in the past 20 to 30 years. Our analysis of Chinese policy reveals that since 1978 China has undergone a "long transition towards a market-based S&T system."[54] This transition and development has clearly played a key role in the rapid economic growth that China has enjoyed in the past decade.

The impressive rise of China's STI policy has accompanied the country's even more impressive economic growth. Since what many call the "great leap forward" from 1958 to 1962, we have witnessed "30 years of opening up and reform, [and] China has established a unique economic and enterprise system, which is very effective for mobilizing resource for economic performance."[55] China's capacity and growth is certainly impressive, and they now boast one of the world's fastest growing economies.[56] The Chinese government's history and capacity of effectively developing and implementing policy is apparent in the STI growth seen within the

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[52] Ibid.
[53] Cao, Cong, Richard P. Suttmeier, and Denis Fred Simon. "China's 15-year science and technology plan." *Physics Today* 59, no. 12 (2006): 38-43., 38.
[54] Ibid.
[55] Lundvall, Bengt-Ake; Joseph, K.J; Chaminade, Cristina; Vang, Jan. *Handbook of innovation systems and developing countries: building domestic capabilities in a global setting*. Edward Elgar. Cheltenham, UK. 2011. 119.
[56] "World Bank - Current GDP by Country." GDP (current US$) | Data. 2016. 2017.

state.

However, it is important to note that prior to 1980 China had implemented science and technology policies but no innovation policy. From this time until now, China's STI capacity has observed substantial changes. Many believe that these changes contributed significantly to the state's sustained growth in the past two decades. Upon introducing the market economy and making economic growth their top priority, China's STI policy entered a transition phase. Chinese scientists Xielin Liu and Jianbing Liu identify the following four transitions: (1) the emergence of the market as the primary force behind the innovation system; (2) The evolution from a system centered on state-owned companies (SO) to a system of SOs, foreign related companies and private companies; (3) A general opening to the world; and (4) the beginning of the decentralization, which has allowed regional governments more autonomy to develop innovation.[57] All of these transformations have fostered the steady development of China's STI capacity.

Today China seems to have embraced the importance of STI as a cornerstone of its development. China's desire to foster STI growth is embodied in its "Medium to Long-Term Plan for the Development of Science and Technology," or MLP. Released in the 2006, the MLP shows us the priorities and intentions of Chinese STI development. The MLP reminds us that this Asian giant is poised to truly become a "S&T power" in the near future. The MLP shows us that modern Chinese STI policy prioritizes the development of the state's "indigenous" or national

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[57] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives: innovation systems and policies*. London: Anthem, 2011.

capacity for scientific and technological output. This analyses of modern Chinese STI policy finds that China hopes to decrease its dependence on international technology and innovation. By prioritizing the revitalization of their own innovation systems, China hopes to *create* solutions to many of the significant problems that may hinder the sustainability of their growth. We find that despite many of the challenges China faces, effective political organization and implementation of policy has generated substantial STI growth.

Universities, Research Institutions, and Scientific Development

The primary goal of China's modern STI policy is to develop what is translated from Chinese as "indigenous" innovation. Chinese scientists believe that the essence of this policy is to strengthen innovation capability in domestic companies. The main routes to indigenous innovation are: original innovation based on basic research, integrative innovation and second innovation."[58] This "basic research" is an area that, as we have mentioned, is facilitated primarily by universities that are recognized by national science and research organizations. The MLP states, "basic research has become a part of the international competition of overall national strength. China Must put the emphasis on basic research in order to achieve national goals and solve key problems in the future."[59] This type of basic research is considered to be essential to the growth of any NSI. Since the beginning of China's major transformation in the 1980s, universities have become major contributors of original research and science development. Prior

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[58] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives: innovation systems and policies*. London: Anthem, 2011. 152.
[59] "China to strengthen basic research." People's Republic of China Government Website. Accessed April 16, 2017. http://www.gov.cn/english/2006-02/09/content_183726.htm.

to this transformation the majority of China's research was produced by Government Research Institutions (GRI). Now, universities and research bodies take a central role in China's modern efforts to bolster basic scientific output.

With the release of the MLP in 2006, China pledged to invest 2.5% of its GDP in R&D by 2020, which is an increase from 1.3% in 2005.[60] In 2013, the UNESCO Institute for Statistics reported that just over 2.0 % of China's GDP had been devoted to R&D.[61] As a percentage of GDP, China is second only to the United States in R&D expenditure.[62] This R&D funding is distributed by government STI institutions (primarily through the Ministry of Science and Technology- MOST) to universities, research organizations (both GRIs and private) and some technology and innovation firms. Of the three major national programs devoted to the development of basic sciences, roughly 60% of the projects funded are those overseen by a university.[63] While the number of GRIs has gradually decreased, many larger "mission-oriented" science projects led by GRIs receive R&D funding to undertake research addressing "strategic areas such as energy, information, health and materials."[64] In 2015, the National Bureau of Statistics of China reported that over 70% of Chinese "research institutions" were higher education organizations.[65] This percentage of University involvement marks an increase from

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[60] Cao, Cong, "China's 15-year science and technology plan." 2006. 38.
[61] "UNESCO Science Report 2010." *United Nations Educational, Scientific and Cultural Organization* , 2010. Accessed April 16, 2017.
[62] "Technology Statistical Data." National Bureau of Statistics of China. 2017.
[63] "MOST: Chinese Science and Technology Statistics, 2006 ." Ministry of Science and Technology of the People's Republic of China. Accessed April 16, 2017. 138.
[64] Ibid.
[65] "China Statistical Yearbook 2016." China Statistical Yearbook-2016. Accessed April 16, 2017.

65% in 2011.[66]

China's R&D spending, increasing investment in university research, and overall focus on original scientific research, tell us several things about China's modern STI strategy. First, China's dedication to the development of basic scientific capacity displays a desire to create a "research tradition that is conducive to creative achievements." [67] This is something that has not been present in China's past. Despite "increasingly generous funding" and the "swelling ranks of research personnel," China has failed to retain their "best and brightest" scientists or substantive qualitative gains in research. [68] China's investment in basic research displays a desire to create a national culture and engine for original scientific innovation. In many ways, this investment into the expansion and revitalization of Chinese research creates a framework for STI growth. In today's economy, "Science is not a luxury for less-developed countries, but an important precondition for contemporary economic development."[69] By strengthening its "indigenous" scientific capacity, China has laid the groundwork for further innovation and economic growth.

In evaluating China's efforts, several trends are worth noting. One of the most effective ways of measuring a state's scientific output is by analyzing publications and citations. Over the past two decades, the number of papers published by Chinese researchers has increased greatly. Both in English and Chinese, the sheer increase in volume of scientific publications demands attention. While China's numbers are relatively low when comparing to the most developed

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[66] Ibid.
[67] Cao, Cong, "China's 15-year science and technology plan." 2006. 40.
[68] Ibid.
[69] Bernardes, Américo Tristão, and Eduardo Da Motta E Albuquerque. "Cross-over, thresholds, and interactions between science and technology. (2003). 865.

countries, United States, Japan, it is the rate of China's growth that displays their scientific promise. China's citation rate has also increased at an exponential rate in the past ten years, and is now the "5th leading nation in terms of its share of the world's scientific publications."[70] The growth rate of citations is an excellent indicator of an increase in quality of research as well.

The accelerated rate of scientific publications and citations can largely be attributed to the aforementioned strategies to increase R&D funding. The availability of grants, and support of original research is much higher now than it ever has been before in China. This has resulted in a substantial rise in research and publications. However, several other strategic policies have also contributed to the growth of Chinese scientific research. The Chinese government, universities and research institutions have offered incentives for publication. "Researchers can win prizes and awards for publishing in highly ranked journals."[71] Another factor that has contributed to this rise of Chinese science is the return of many overseas scholars. China's economic growth, and the "development of policies that are favourable for returning scholars," has resulted in the return of many overseas scholars.[72] In 2004, 81% of Chinese Academy of Sciences scholars were returning scholars.[73]

Technology, Innovation and Integration

Prior to the aforementioned scientific transformations beginning in the 1970s, Chinese

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[70] Zhou, Ping, and Loet Leydesdorff. "The emergence of China as a leading nation in science." *Research Policy* 35, no. 1 (February 2006)
[71] Ibid., 140
[72] Zhou, Ping, and Loet Leydesdorff. "The emergence of China as a leading nation in science." *Research Policy* 35, no. 1 (February 2006). 2.
[73] Ibid.

technology policies were largely designed to bolstering military capabilities and some other specific sectors. During this time China became technologically dependent on imports from countries like Japan and Germany. In the 1990s, China witnessed a large increase of interest from multinational corporations and foreign direct investment. In response the government instituted a number of policies to protect domestic companies, requiring multinationals to sell the majority of their product elsewhere.[74] Eventually Chinese technology policy turned to the development of nanotechnology with the "aim of tracking and catching up with the development of high technology in developed countries."[75] While this sparked some technological progress, the R&D of China remained largely disconnected from commercial application. Compared to the development of science and research, technological innovation in China struggles to break free from a dependence on foreign innovation.

While some progress has been made, foreign invested enterprises have accounted for more than 85% of all high-tech exports.[76] Nevertheless, China aims "to have the annual number of patents granted to Chinese inventors and the average number of cited scientific publications of Chinese authors reach the top five worldwide."[77] To accelerate technological and innovative growth, three main policies are important to consider. First, the influx of public funding for R&D described by the MLP is intended to jump-start Chinese innovation, similar to how it affected

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[74] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives: innovation systems and policies*. London: Anthem, 2011. 143.
[75] Ibid., 146.
[76] "Technology Statistical Data." National Bureau of Statistics of China. Accessed April 16, 2017.
[77] Wong, Chan-Yuan, and Lili Wang. "Trajectories of science and technology and their co-evolution in BRICS: Insights from publication and patent analysis." *Journal of Informetrics* 9, no. 1 (2015): 90-101., 91.

science growth. Second, a new tax policy has made company R&D expenditures, necessary for innovation, "150% tax deductible, thus effectively constituting a net subsidy, as well as allowing accelerated depreciation for the equipment worth up to 300,000 Chinese Yuan (¥)."[78] Finally, public procurement of technology has also become a widely used tactic by Chinese government organizations to incite innovative growth.

The increase of R&D funding offered in light of the MLP, provides a much needed support to China's sectors of innovation. The portions of these funds dedicated to basic scientific research have been fairly effective. However, because of stunted innovative growth in the past, much of the state's R&D funding is awarded to experimental development (77%) and applied research (17.7%).[79] This allocation of funds to applied research is an increase from just 22% in 1998.[80] Of the organizations that received this funding in 2005, 67% were private businesses and 26% were GRIs. In 1998 only 44% of organizations receiving funding were private businesses.[81] It is also important to note that just 0.9% of China's R&D funding was not utilized domestically. The utilization of R&D funding within Chinese borders reminds us of the state's quest to develop "indigenous" innovation. Also worth noting is the primary allocation of R&D to experimental innovative development in an effort to boost technological development.

A critical piece of China's strategy to incentivize innovation comes in the form of an aggressive tax deduction plan. China offers a number of incentives for the development of "big"

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[78] Cassiolato, José Eduardo. *BRICS and development alternatives.* 2011. 144.
[79] "MOST: Chinese Science and Technology Statistics, 2006 ." Ministry of Science and Technology of the People's Republic of China. Accessed April 16, 2017.
[80] Ibid.
[81] Ibid.

science and technology. In a global survey of R&D tax incentives, Deloitte describes one of China's tax deductions, which is equal to 150% of the qualifying R&D expenses as a "super deduction."[82] Additionally, any tax losses "attributed to R&D deduction claims can be carried forward up to five years."[83] In addition to this super deduction, "a reduced 15% enterprise tax rate" is available for companies that are considered to be "high and new" technology enterprises. Among the "state encouraged" areas that are considered to be of this status are Biological and new medical technology, new materials technology, and energy conservation technology.[84] These tax incentives make the development of new technologies especially lucrative for private firms. While other BRICS countries have similar deduction plans, China's is worth noting because of its focus on organizations dedicated to "new technology." Of course, the areas that China considers to be part of this sector are all facets of development necessary to the economic growth China hopes to sustain. Without breakthroughs in energy and environmental technology, some Chinese scholars believe China's growth will not be able to sustain its pace of past years.[85]

The Chinese government's procurement of R&D technology is a policy that is and will continue to be "widely used" to boost indigenous innovation.[86] By purchasing and developing R&D equipment, the Chinese government provides resources that would otherwise be very costly for private firms. By developing "big-science" projects China hopes to observe a sort of spill-over effect in technology growth. China's development of a number of supercomputers is

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[82] Deloitte - "2015 Global Survey of R&D Incentives." Deloitte . October 2015. 5.
[83] Ibid.
[84] Deloitte - "2015 Global Survey of R&D Incentives." Deloitte . October 2015. 5.
[85] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives: innovation systems and policies*. London: Anthem, 2011.
[86] Ibid., 153.

an apt example of how public procurement can spur innovation growth. By fronting the high cost for this new technology, the government provides a new product to the technology community at low cost while providing space for a new sector to grow. Now, these supercomputers are used for advanced research, running incredibly complex simulations, analyzing oilfields, and other specialized purposes.[87] Similar to increasing R&D funds in experimental fields and tax incentives, public procurement play a major role in China's strategy to accelerate indigenous innovation.

We can measure how effective China's strategies to spark innovative growth have been by analyzing national patent information. In 2015 the World Intellectual Property Organization (WIPO) reported that over 1 million IP filings were made compared to just 31,000 in 2001.[88] Patent applications submitted by Chinese residents increased from just 30,000 in 2001 to 968,000 in 2015.[89] It should be noted that a large number of emerging and middle powers witnessed increases in patent applications. For various reasons, many states around the world witnessed annual increase in patent applications of about 9% between 2012 and 2013. However, China's patent filings increased 26% from the year before, which was the fastest growth rate in the world. Today, China leads the world as the state with the most patent applications.[90]There are two important conclusions from China's technological growth. First, China's overall technological and innovative growth signify the effectiveness of their strategy to boost related

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[87] Williams , Sophie. "China develops new supercomputer that is 10 TIMES faster than the current quickest machine in the world ." Daily Mail Online. November 02, 2016.
[88] "WIPO: Statistical Country Profiles." WIPO - World Intellectual Property Organization. 2016.
[89] Ibid.
[90] Ibid.

fields. Second, the increase of patent applications by Chinese residents show us that China's efforts to spark "indigenous growth" have been largely successful.

Reflecting on Chinese STI Policy

There is no doubt that STI development has contributed in a major way to the economic growth China has enjoyed in the past 20 years. Today it is clear that China continues to recognize the importance of STI in modern economic and state development. In our analysis of scientific article publications and patent information, it seems that increases in R&D funding and other STI policies have been effective thus far. Nevertheless, it is important to recognize that China has, and will continue, to encounter many challenges if it is to become a leading STI power by 2050. It is unclear how China's efforts to develop indigenous STI will coexist and interact with its need to engage with global technology trends and development. Will China's ambitions be hindered by China's aging population? Will China's focus on applied research effect a comprehensive development of their NSI? There is no denying the rapid growth of STI capacity in China. Nevertheless, these challenges may inhibit the sustainability of this growth.

Regardless of the future success of their strategies, China's current STI policies contribute several important perspectives to our understanding of the role of the state and STI in state development. In response to globalization and rise of what some call the knowledge economy, China has sought to jump-start STI growth through the implementation of one of the world's "most comprehensive and advanced S&T systems."[91] The implementation of substantial

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[91] Cao, Cong, "China's 15-year science and technology plan." 2006. 43.

R&D funding, tax incentives, and direct state procurement are all examples of strong state intervention. The resources and strategies of the state are at the core of STI growth in China. Growth that has incentivized firms to develop technology in China. Furthermore, the clear and organized implementation of STI policy in China has clearly allowed STI to develop rapidly. Strategic STI investment appears to be of increasing importance to China and states with similar ambitions of promoting competitive growth in the global economy. Many believe that the continued growth of STI will be even more important in the years to come if China hopes to sustain this growth. Without significant innovative breakthroughs, China's economic growth may be stunted by a lack of necessary or cutting-edge technologies. The importance of STI growth as a precondition of economic development should not be overlooked. Furthermore, STI capacity should be recognized as a fundamental driver of sustainable growth for today, and for the future. The ability of the state to continuously implement effective STI policy is paramount to modern economic growth.

Brazil

Compared to the systematic advancement of China, the history of STI policy in Brazil can be classified as disconnected and delayed. Despite taking massive leaps economically in the past 20 years, STI seems to be largely disconnected from industry and commercial markets in Brazil. Nevertheless, Brazil's STI policy of today reflects several realities of STI policy. First, Brazil, more recently than China, has recognized the fundamental role of STI in modern, sustainable, economic growth. Secondly, aspects of Brazil's STI policy display the economic

advantages of STI integration into industry, and many of the challenges that arise when innovation and industry are disconnected.

Brazil's rapid development of industry and economy began in the 1960s. The military government that controlled Brazil from 1964-1985 is remembered both for its brutal state intervention and its unprecedented economic growth. The massive economic development during this period helped to transform Brazil's industrial base into what some considered to be the "largest and most sophisticated" in the world at the time.[92] During these years, "Industrialization and economic growth became the overriding goals of government economic policy" and the "state became the organizer and protector of economic activity."[93] In what became known as the "Brazilian Miracle," Brazil's industry created a base for what would become, a South American economic giant.

Despite the political instability of the past half century, Brazil's STI fields remained relatively undisturbed. That being said, Brazil's STI framework was little more than a handful of public research institutions. During this time Brazil did not have a cohesive innovation strategy. However this economic growth and international trends forced the government to confront a fundamental disconnect between "scientific and technological institutions" which was "preventing the Brazilian scientific infrastructure from producing innovations."[94]

Despite the establishment of a number of organizations designed to develop STI, growth

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[92] Reid, Michael. *Brazil: The Troubled Rise of a Global Power*. New Haven: Yale UP, 2015. 110.
[93] Ibid., 108.
[94] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives."* 2011. 48.

in Brazil was sluggish throughout the 1980s. Political disorganization challenged the uniform development of technology. The majority of firms did not show any major growth. Many organizations involved in S&T were not devoted solely to R&D. Needless to say, STI was not a priority during this period. Consequently, the R&D and technological advancements needed to further Brazil's primary economic activities were undertaken by the state. "S&T policy instruments linked to projects to develop local production capacity were set up in strategic sectors."[95] Brazilian officials hoped that this would have a spillover effect, which did not occur. Even after this period, in the 1990s, monetary and economic instability greatly limited any STI growth.

Consequently, Brazil's STI capacity has grown at a much slower rate than the country's economic growth. With the exception of a drop in the past three years, Brazil's GDP has increased rapidly. As we will discuss, Brazil has struggled to create STI systems that are able to connect their booming industry with STI research and development. In recent years, Brazil has felt the effects of these STI shortcomings. Patent numbers, and R&D activities amongst firms are relatively low, "leaving most of the funding efforts to the public sector (55%)."[96] Brazil has implemented a number of strategies to develop STI capacity and innovative growth. The"Greater Brazil Plan" (2011) and the National Strategy in Science Technology and Innovation (ENCTI) are two such policy strategies. They describe increases in R&D funding, increases in scholarships, R&D tax deductions, as well incentives for innovation and commercial

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[95] Ibid.

[96] "UNESCO Science Report 2010." *United Nations Educational, Scientific and Cultural Organization* , 2010.

integration. Brazil's capacity to implement the level of innovation necessary foster state development is lagging behind compared to China and other developed regions. Nonetheless, Brazil's current STI policy reflects the importance of integrating R&D with innovation and industry in today's knowledge economy.

Universities, Research Institutions, and Scientific Development

"Brazil went through the modernization process late" compared to many other states of similar economic stature.[97] Consequently, the development of universities as drivers of scientific research came later as well. The few laboratories and institutes that conducted the majority of scientific research prior to 1930 were not focused on building a foundation of basic research. The University of Sao Paulo (1934) and the University of the Federal District (1934) were "originally organized with the purpose of conducting activities related to "basic research."[98] Developing this basic research has been done relatively effectively in the past 40 to 50 years. Like China, Brazil has recognized the importance of creating a basic foundation for future innovation.

Since the establishment of a number of universities, higher education in Brazil has developed quickly. While universities are not global centers of research, Brazil's universities are considered to be some of the most scientifically capable in South America. Brazil's "Federal University Expansion and Restructuring Program offered a revised student loan program that boasted impressive results. The total number of undergraduate degrees awarded doubled between

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[97] IDA: Innovation Policies of Brazil." *Institute for Defense Analyses* , September 2013. 2.
[98] Dias, Rafael, and Milena Serafim. "Science and technology policy in Brazil: An analysis of the recent period." *2011 Atlanta Conference on Science and Innovation Policy*, 2011. 2.

2000 and 2010.[99] Within science, technology, engineering and math (STEM) fields, the number of undergraduate degrees awarded jumped from 650,000 in 2005 to over 750,000 in 2009.[100] Similar trends can be observed amongst Brazilian post-grads. Between 2007 and 2013 the number graduate students enrolled "flourished," with the number of PHD's granted rising by 30%.[101]

In conjunction with the increase of what many call "knowledge workers," Brazil has pursued the development of R&D by substantially increasing funding, and incentivising research in universities. This was initialized by the reorganization of federal STI organizations. Working closely with the STI community, the Ministry of R&D in Brazil has worked to develop research outputs. Between 1999 and 2002 twelve sectoral funds were created to develop R&D development within the sciences.[102] This reorganization was accompanied by a substantial increase in R&D funding. Between 2004 and 2013, the percentage of national GDP spent on R&D increased from .97% to 1.16%.[103] The "Greater Brazil Plan" outlined for the state to have achieved 1.8% by 2015.[104] Over 60% of this funding is allocated to Universities.[105]

Additionally, the aforementioned federal restructuring and creation of sectoral funds led to the development of integrated research projects. With revamped funding, the Ministry of S&T awarded scholarships and grants; to university research efforts. Moreover, Brazilian S&D

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[99] IDA: Innovation Policies of Brazil." *Institute for Defense Analyses* , September 2013. 35.
[100] Ibid.
[101] *UNESCO science report: towards 2030*. Paris: UNESCO, 2015. 214.
[102] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives."* 2011. 49.
[103] *UNESCO science report: towards 2030*. Paris: UNESCO, 2015. 215.
[104] OECD - Research and development (R&D) - Gross domestic spending on R&D. 2016.
[105] Ibid.

organizations offered financial support of joint research "partnerships between scientific and technological institutions and enterprises."[106] Supporting these partnerships continues to be a emphasis of Brazilian STI policy.

Brazil's research growth amongst universities has been substantial, but the R&D capacity of firms in Brazil remains underdeveloped. Currently, Brazil offers a number of tax incentives for private firms that engage in focussed scientific research. As we have discussed, Brazil has struggled to integrate applied research with industry in many areas. R&D tax incentives are an effort to counteract; this trend. Similar to China, Brazil offers a base "super deduction equal to 160% of R&D expenditure."[107] Additionally, for firms that increase the number of researchers "dedicated exclusively to research projects by up to 5% in a year, the super deduction increases to 170%."[108] Entities that increase over 5% in a year are granted a 180% deduction of qualifying expenses.[109] These tax incentives encourage private, focused research, and the incremental growth of such research.

Since the start of the 21st century, Brazil's efforts to grow the scientific research capacity have been largely effective. Like our analysis of China, we can measure Brazil's policy by examining publications, citations and their growth. Globally, Brazil is the 15th largest publisher of academic works, with China and South Africa in 2nd and 34th respectively.[110] Between 2002

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[106] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives."* 2011. 52.
[107] Deloitte - "2015 Global Survey of R&D Incentives." Deloitte . October 2015. Accessed March 2017. 8.
[108] Ibid.
[109] Ibid., 9
[110] SJR: Scimago Journal and Country Rank ." SJR - International Science Ranking. 2016

and 2012 Brazil's output of published research works increased by 9%.[111] It is worth noting that Brazil's scientific publications increased by 31% between 2008 and 2012.[112] As we discussed previously, Brazil's desire to achieve aggressive economic growth has led to the intense development of several sectors. Consequently, Brazil is now a clear leader in agricultural sciences amongst other emerging economies.

While this growth in scientific capacity does not rival that of China, Brazil's strategy to grow scientific research capacity shows us several things. First, Brazil has recognized the importance of scientific and research capacity as a component of spurring economic growth. The development of universities, the reorganization and reallocation of federal funds, as well as research incentives reflect this. While Brazilian STI policy seems to lack a cohesive national agenda, Brazil's strategy to increase scientific capacity has been successful. Increases in PhD's awarded, scientific publications, and publications cited show us that Brazil has begun integration into the transnational knowledge economy of today.

Technology, Innovation and Integration

It would seem as though scientific development in Brazil has seen growth in the past 20 years. Technological and innovative advancement however, has been less successful. As was previously mentioned, Brazil has struggled to integrate the limited focussed research in the state to areas of industry that need it the most. With a well diversified economy, many Brazilian sectors have been very successful. However, as we have seen in China, sustainable growth in

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[111] Ibid.

[112] *UNESCO science report: towards 2030*. Paris: UNESCO, 2015. 36.

many fields is dependent on corresponding STI development. Federal efforts to foster innovation are complicated, and lack one aim or cohesive vision. There are dozens of organizations that organize, implement, and oversee the distribution of technological and innovation funds. Nevertheless, policies in these areas prioritize the development and integration of new technologies by, and for, the private sector. In this section we will examine Brazilian state action designed to address this priority, and how effective they have been. Furthermore, we will examine areas of Brazil's economy that have observed significant growth as a result of focussed research and innovation. Conversely, other Brazilian sectors display the consequences of STI development that is not paced with a state's rapid industrial growth.

Brazil's STI policy in recent years has sought to close the gap between university research and industry. Firms in Brazil suffer from a "shortage of scientists and engineers employed in the private sector, as the vast majority of PHD holders seek careers in academia."[113] Consequently, companies lack focused areas of research which would foster industry-driven innovation. Since the recent addition of innovation policy to S&T strategy, in 1990 several organizations have been created to further private innovation. Financer of Studies and Projects (FINEP) is a branch of Brazil's Ministry of S&T that offers loans to private projects of innovation. The Brazilian government has also instituted an "Economic Subvention Program" which offers grants directly to private companies for innovative projects. Finally, the state's "Action Plan for Science, Technology and Innovation for National Development" increased federal fiscal support of private R&D investment. These funds are a portion of the 1.9% of total

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[113] "IDA: Innovation Policies of Brazil." *Institute for Defense Analyses* , September 2013. 19.

GDP that Brazil allocates for R&D.[114]

Brazil has also implemented a number of laws and tax incentives that target the development of private innovation. Such laws include The Asset Law, which "creates favorable fiscal incentives and depreciation schemes for R&D investments.[115] The Innovation Law "creates fiscal advantages and subventions for the financing of partnerships between private sector agents and between them and universities and research centers."[116] Similar to increases in funding, these laws are clearly designed to integrate research with private innovation. More recent attempts to promote innovation come from the state's Greater Brazil Plan. This plan "relies on greater trade protectionism measures to promote domestic industry and exports through local content requirements, increased investments in the domestic industry and increased import taxes.[117] This strategy is an effort to support domestic companies attempting to remain competitive with foreign firms, while also indirectly encouraging domestic innovation. The slogan of the Greater Brazil plan is "innovate to compete, compete to grow." This sentiment is certainly echoed in Brazil's direct allocation of ever-growing funds to innovative fields and the implementation of trade laws to support private domestic innovation.

In addition to these trade-related laws, Brazil has also implemented several tax incentives to boost private innovation. Firms that have patents registered, are allocated a 20% tax deduction for costs incurred developing that patent. This deduction comes in addition to the aforementioned

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[114] "IDA: Innovation Policies of Brazil." *Institute for Defense Analyses* , September 2013. 19.
[115] Motta, Tonaldo. "Eco-Innovation in Brazil." Proceedings of Global Forum on Environment on Eco-Innovation OECD, Paris . 2009. 4.
[116] Motta, Tonaldo. "Eco-Innovation in Brazil." Proceedings of Global Forum on Environment on Eco-Innovation OECD, Paris . 2009. 4.
[117] "IDA: Innovation Policies of Brazil." *Institute for Defense Analyses* , September 2013. 25.

super deduction for firms dedicated primarily to R&D.[118] While Brazil has historically limited focused efforts to bolster innovation to several specific fields, these deductions are not limited to any one sector of industry.

The results of Brazil's efforts to encourage and integrate innovation, especially amongst private firms, have been mixed. Some growth has been observed, but the financial crisis in Brazil that worsened in 2011 has left the integration described in the Greater Brazil Plan unrealized. Between 2001 and 2015 the total number of patent applications increased from 20,639 in 2000 to 30,395 in 2012, growing by 62%.[119] This "rate pales in comparison with that of scientific publications of the same period (308%).[120] Brazil's economic situation has continued to deteriorate and innovative structures have suffered. In their most recent innovation survey, the Brazilian Institute of Geography and Statistics (IBGE) found that all Brazilian firms reported a drop in innovation activity since 2008. "This survey covers all public and private firms in the extractive and transformative sectors, as well as firms in the services sector involving technology, such as telecommunications and internet providers, or electric power and gas utilities."[121] IBGE's results of their 2013 study stand in stark contrast to their surveys of 2003-2001 and 2009-2001 which revealed substantial growth in these areas.

Despite their renewed effort to develop innovation, Brazil's efforts have been hindered by financial instability and the ineffectiveness of many of the aforementioned strategies. Since 2011, Brazil has found itself in a financial crises as a result "weaker international commodities

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[118] Deloitte - "2015 Global Survey of R&D Incentives." Deloitte . October 2015. 8.
[119] *UNESCO science report: towards 2030*. Paris: UNESCO, 2015. 222.
[120] Ibid.
[121] Ibid.

markets, on which Brazil is highly dependent."[122] With Brazil's spending overtaking its revenue (deficit of .5% of GDP in 2014) public support of innovation has slowed. Additionally, the majority of R&D funding goes to universities (61% of all R&D funding), with only 5.91% allocated for the development of industrial technology.[123] In addition to the lack of fiscal support for private innovation, Brazil's "custo Brasil" (Brazil Cost) has long been known to plague the overall value of investment in the country. A limited infrastructure, logistical challenges, and troublesome business regulations make the cost of doing business in Brazil very high.[124] For many firms, Brazil's tax deductions and recent attempts to support innovative progress do not escape the shadow of the "Brazil Cost."

Despite current struggles, some Brazilian sectors reflect the growth that *can* occur amidst effective STI development and integration. Petroleum giant Petrobras is a multinational corporation largely controlled by the Brazilian federal government who owns just over 50% of their publicly traded shares. Petrobras invests heavily in R&D (1.5 Billion in 2011) and continues to increase their investments.[125] The petroleum giant operates six research centers in partnership with Brazilian universities and research institutions. Petrobras alone "is responsible for about 10% of all fixed capital investment in Brazil" and "registers more patents than any other individual company in Brazil."[126] While scandal has affected Petrobras's and, unavoidably,

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[122] Ibid., 211.
[123] MST "Ministry of Science and Technology ." Ministry of Science, Technology Innovation and Communications Brazil . 2012.

[124] *UNESCO science report: towards 2030*. Paris: UNESCO, 2015. 215.
[125] "IDA: Innovation Policies of Brazil." *Institute for Defense Analyses* , September 2013. 12.
[126] *UNESCO science report: towards 2030*. Paris: UNESCO, 2015.220.

Brazil's growth, this firm is a prime example of how the effective integration of technology and continued development of innovation can create economic growth.

Other sectors that have benefited from the consistent integration of innovation include aviation, and agricultural sciences. Companies like the Brazilian manufacturer Embraer (aviation), and research group Embrapa (agriculture), are both examples of economic and technologic growth as a result of direct, continued state support. Both of these firms were created by the state and have become major players in international aviation and agricultural technologies. These groups were conceived to address specific areas essential to Brazil's growth in the 60s and 70s. Now, they are fundamental pieces of advancing technology in their respective fields, and display how innovation can spur economic growth.

Embraer was initially "created to provide transportation for monitoring and assessing Brazil's vast stretches of relatively isolated territory."[127] Now, Embraer operates a number of research institutions throughout Brazil. Including a joint sustainable aviation biofuel research center, that is operated in conjunction with Boeing. Embraer has also partnered with Brazil's Aeronautical Technology Institute (ATI) to develop a professional master's program. This partnership functions as a pipeline for "aeronautical and aerospace engineers to meet Embraer's human resource demands."[128] In analyses of Embraer's value for the Brazilian economy, the authors from the Columbia school of business conclude the following. "Government involvement in creating and supporting the firm, even after privatization was essential to Embraer's success. This success, in turn, created important externalities for the Brazilian

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[127] "IDA: Innovation Policies of Brazil." *Institute for Defense Analyses,* September 2013. 13.
[128] Ibid.

Government."[129] After the privatization of Embraer, the company remains a source of private, domestic, innovation development that creates economic growth. This type of integration of innovation to the private sector is something that Brazil continues work towards.

Embrapa describes itself as "a technological innovation enterprise focused on generating knowledge and technology for Brazilian Agricultural."[130] Created in partnership with the Brazilian Ministry of Agriculture, this research cooperation is devoted to the development of agricultural science and technology. Embrapa employs 2,444 researchers, and operates 46 research centers throughout the country and four laboratories internationally.[131] Brazil's investment in agricultural research has paid off. Embrapa has contributed to the "development of new crops specific to the soil and climate conditions in Brazil," the adaptation of "soybeans for tropical climates" and development of sugarcane as an efficient ethanol crop.[132] Brazil is now the second largest producer of soybeans in the world.[133] Developments in agricultural science has also contributed to the emergence of a biotechnology sector in Brazil. Similar to Embraer's connections to the ATI , Embrapa's capacity is bolstered by the "high level of education in fields related to the agricultural sector, and in basic research" at many Brazilian universities.[134] The integration of state driven research, with the agricultural sector in Brazil is a testament to the

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[129] Broad, Eleanor, Ben Choi, Daniel Drum, and Sergio Lagunes. "Embraer's Creation of Value for Shareholders and the Brazilian Economy." *Chazen Web Journal of International Business* Winter (2005): 1-19.
[130] "Embrapa - Who We Are." Embrapa.Brazil. 2010. Accessed April 16, 2017.
[131] Ibid.
[132] "IDA: Innovation Policies of Brazil." *Institute for Defense Analyses,* September 2013. 12.
[133] Ibid., 11.
[134] "OECD - Research and development (R&D) - Gross domestic spending on R&D - OECD Data." 2016. 106

importance of innovation integration, especially in Brazil.

Reflection on Brazilian STI Policy

Brazil has enjoyed substantial economic growth in the past 20 years. With a diverse economy, and an abundance of natural resources, Brazil's potential is clear. However, financial crises and a lack of an effective national trajectory have left the STI development in Brazil very uneven. Regionally, some institutions have proven effective at producing scientific research. By revising student loan programs, the state has seen growth in undergraduate and graduate enrollment. Scholarly publications, especially scientific ones, have been on the rise, indicating some steps in the right direction. However, the large portion of Brazil's R&D funding is concentrated within certain regions. For example, the state of Sao Paulo receives 86% of the state's higher education spending on R&D. [135] As a result the quality of higher education and the capacity of research institutions varies greatly from state to state. Nevertheless, Brazil's education reforms, tax incentives for research, and Brazil's aspirations to increase R&D funding, shows us that Brazil has recognized the role STI development plays in fostering economic growth.

As we have seen Brazil's modern STI policy is primarily concerned with bridging the gap between research and innovation in private sectors. By instituting trade regulations and various incentives for private firms to engage in R&D, Brazil hopes to close this gap. Despite these efforts, Brazil's patent growth remains sluggish in comparison to increases in scientific

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[135] "OECD - Research and development (R&D) - Gross domestic spending on R&D - OECD Data." 2016. 227.

publications. The late introduction of innovation policy and a lack of cohesive innovative strategy today, have left Brazil's private sector detached from high levels of research.

However, Brazil is a global leader of R&D and innovation in several sectors. Growth in these areas has been pushed by focused, organized, state support. These success stories display the critical role that the state plays in public and private STI development. Petrobras and Embraer are both examples of this. With direct state involvement, these two companies have risen to be global competitors in their respective fields. More importantly, these multinational companies are now drivers of research and innovation within Brazil. Furthermore these developments in STI has led to economic growth. Embrapa is another example of how state involvement can spark economic growth through the integration of innovation. By developing an efficient way of providing applied technologies to the agricultural sector, Brazil has modernized and maximized their production methods.

Brazil has struggled to integrate much of their industry with the research community that is growing in the country. Consequently, innovation capacity and application has been developing slowly. However, Brazil has implemented a number of policies as a part of a larger strategy to develop STI in the state. While financial crisis has inhibited the implementation of this strategy, these policies are a testament to Brazil's desire to increase their STI capacity. The sectors that have seen significant growth in these areas, have done so with the organized support of the state. These sectors are a testament to the importance of state involvement in developing economic growth as the international community shifts towards a knowledge economy.

South Africa

As we have seen, understanding STI policy and its implementation must be done within the specific context of any given country. Despite the parallels many draw between the various BRICS states, historical and political backgrounds inevitably shape how these countries engage STI policy. South Africa's history of division, apartheid, and relatively recent transition to democracy, makes for a very young political dispensation. This has presented a number of challenges for the development and implementation of state policy in the post-apartheid era. However, since the end of apartheid and this political transition in 1994, the state has seen massive change and growth. South Africa is now one of the strongest economies in Africa and like the other BRICS, has observed rapid economic growth.[136]

As South Africa emerged from its dark past in the late 1990s so did its focus on STI. Like many other "middle-income" or "upper middle-income" states, South Africa has sought to refocus its efforts to develop STI. Today, South Africa's STI policy is outlined in the Ten-Year Plan for fostering "Innovation Towards a Knowledge-Based Economy." The aim of the Ten-Year plan is to "help drive South Africa's transformation towards a knowledge-based economy, in which the production and dissemination of knowledge leads to economic benefits and enriches all fields of the human endeavor."[137] This description of the plan's goal is almost a word for word copy of the theoretical purpose of the NSI. In an analysis of South Africa's innovation policies, scholars Glenda Kruss and Jo Lorentzen conclude that the state's "new science and

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[136] "World Bank - Current GDP by Country." GDP (current US$) | Data. 2016. Accessed April 16, 2017.

[137] DST - South Africa. Department of Science and Technology. *DST - Innovation Towards a Knowledge Based Economy Ten-Year Plan for South Africa*. Johannesburg: DST, 2007., I.

technology policies were systematically redesigned in the mold of the national innovation system approach."[138] There is no doubt that South Africa appreciates the importance of STI development. The Ten-Year Plan states, "The Government's broad developmental mandate can ultimately be achieved only if South Africa takes further steps on the road to becoming a knowledge-based economy."[139]

The Ten-Year Plan is the most recent strategy of a series of STI developments in South Africa that have taken place over the course of almost two decades. All of these have been produced by the South African Department of Science and Technology (DST). Beginning during the 1990s, South African STI began to transition into what it is today. This process began with the formulation of a policy White Paper on Science and Technology: Preparing for the 21st Century. "The goal articulated in this document was to achieve an improved and sustainable quality of life for South African citizens in the context of a competitive global economy through the establishment of an efficient, well-coordinated and integrated system of technological and social innovation."[140] The White Paper outlined the basic requirements for an S&T policy that would allow South Africa to move towards a knowledge based economy. Essentially, this policy text provides the reasoning and goals of establishing a strong NSI. Since its beginnings, South African STI policy has brought the development of their NSI to the core of overall state development. The White Paper on S&T addressed a broad range of realities that the state

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[138] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives.* 2011. 163

[139] DST - South Africa. Department of Science and Technology. *DST Strategic Plan for the Fiscal Years 2011 - 2016.* 2011., IV.

[140] Cassiolato. *BRICS and development alternatives.* 2011. 164.

perceived could be enhanced by a strong NSI. Today, the belief that all areas of state development can be advanced via progress towards a knowledge-based economy remains core to South African policy.

In addition to the White Paper on S&T, a second strategic text paved the way for the Ten-Year Plan. The National Research and Development Strategy (NRDS), provided a review of the challenges that the state might face in meeting the goal of becoming a knowledge based economy. The NRDS suggested that "disinvestments from R&D on the part of the private sector, too little funding for R&D, an ageing and shrinking scientific workforce, an inappropriate intellectual property system, and a lack of coordination within the NSI itself" all would inhibit the desired development of the South African NSI.[141] This strategic road map echoed many of the ideas of the White Paper while providing specific strategies to meet the STI goals of the state.

However, many scholars believe that the determination and will of South Africa to develop a sophisticated NSI exists in stark contrast with the realities of the state's actual capacity to implement these strategies. While South Africa's proposed strategies are very much in line with the modern STI rhetoric of developed nations, they seem to overlook many the realities of the state. Regardless, South Africa's Ten Year Plan continues this trend of a strong will and intent to create a sophisticated NSI. This plan outlines a number of major interventions to address five core challenges. The five challenges identified are: The farmer-to-pharma value chain to strengthen the bio-economy, space science and technology, energy security, global change with a focus on climate change, and human and social dynamics.

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[141] Cassiolato. *BRICS and development alternatives.* 2011. 166.

In this section we will find that South Africa has clearly identified the growth of STI and the development of their NSI as a priority. South Africa has outlined a number of optimistic goals in their Ten-Year Plan, all of which are projected to support the overall well being of the population. The strategies outlined by this plan, describe a comprehensive plan for transitioning towards a knowledge based economy. However, South Africa is challenged by a lack of inter-organizational coordination and capacity, a shortage of skilled knowledge workers, and an inability to integrate R&D with innovation in critical sectors. Nonetheless, South Africa's Ten-Year Plan is a reflection of the state's major transition towards a knowledge based economy.

Universities and Research Institutions

South Africa's Ten-Year Plan acknowledges that "progress towards a knowledge-based economy will be driven by, human capital development, knowledge generation and exploration (R&D), knowledge infrastructure and enablers to address the 'innovation chasm' between research results and socioeconomic outcomes."[142] As we have discussed education is generally considered to be foundation of any NSI. The Ten-Year Plan sets several goals regarding higher education. By 2018, South Africa hopes to have 9% of "matriculants with university exemption in maths and science," this would be an increase from just 3.4% in 2002.[143] Regarding PhD graduates per year, the DST describes a desire to award 2,200 PhDs per year, an increase from

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[142] DST - South Africa. Department of Science and Technology. *DST - Innovation Towards a Knowledge Based Economy Ten-Year Plan for South Africa.* Johannesburg : DST, 2007. IV.
[143] Ibid., 9.

964 in 2002.[144] Compared to other countries of similar economic standing (Brazil or India), South Africa's levels of undergraduate and especially graduate education are significantly lower. This is due in large part to the country's apartheid past, because of "the limited capacity of higher education system to enrol and supervise PhDs."[145] Many formerly black universities lack the resources to develop programs of higher education. Additionally, R&D investment as a percentage of GDP has not increased which is concerning. South Africa's goals of education advancement are ambitious to say the least, and the state recognizes that much must be done to achieve these goals. While they have taken steps in the right direction, a lack of organization and fiscal support in some sectors has resulted in limited educational and research growth.

To develop their human capital "pipeline," the DST has committed to offering "significant and sustained investment" to universities.[146] "Over the medium term" DST spending has been focused on human capital development.[147] Spending in this area between 2007 and 2008 was 1,103 million South African rand (R), whereas between 2013 and 2014, R2,406 million was budgeted.[148] Expenditures by the DST on human capital development have grown at an annual rate of 9.7%.[149] In addition to increases in spending, South Africa has created several programs that aim to "provide leadership in the creation of an innovative and competitive society

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[144] Ibid., 9.
[145] DST - South Africa. Department of Science and Technology. *DST - Innovation Towards a Knowledge Based Economy Ten-Year Plan for South Africa*. Johannesburg : DST, 2007. 29.
[146] Ibid., 7.
[147] Ibid.
[148] Ibid.
[149] Ibid., 9.

with highly skilled human capital."[150] These programs include Human Capital and Science Platforms, which "implements programmes that address the availability of human capital for STI." Another program, "Emerging Research Areas and Infrastructure," facilitates the "strategic implementation of research equipment in areas of national priority."[151]

As a result of increased spending and the development of programs focused on human capital development, graduation rates have increased. Between 2005 and 2014 undergraduate graduations in science, engineering and technology fields (SET) jumped from 33,506 to 55,574.[152] For reference, this rate is higher than Brazil's, but slightly lower than Russia's. Nevertheless, South Africa's ability to graduate SET students will be a critical piece of developing a strong NSI. The total number of doctoral degrees in South Africa also increased from 1,421 in 2010 to 2,258 in 2014.[153] Increasing PhD production numbers are an area of focus in the Ten-Year Plan. However, South Africa is not only challenged by the quantity of PhDs produced but by the quality of the work of those awarded PhDs. In terms of the quantitative capacity, South African universities produce just under 90% of the country's total research.[154] However, the quality of work produced is less impressive (more on this below).

South Africa's modern STI policy highlights the importance of developing human

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[150] Ibid., 19.
[151] Ibid., 19.
[152] DST - South Africa. Department of Science and Technology. *DST - Innovation Towards a Knowledge Based Economy Ten-Year Plan for South Africa*. Johannesburg : DST, 2007. 5.
[153] Ibid., 7.

[154] *NACI - South African science, technology and innovation indicators 2015*. Pretoria: National Advisory Council on Innovation and the Department of Arts, Culture, Science and Technology, 2015.

capital, and as we have seen, it seems they are moving in the right direction. By analyzing publication data, it can be seen that some growth has occurred. From 2005 to 2014 South African scientific publications increased from 4,797, to over 12,000.[155] While the DST recognizes the importance of increases in R&D expenditure, the state has largely relied on R&D investment by private firms. In 2005 private enterprises spent about R5.5 billion on R&D compared to R3.9 billion by the government.[156] South Africa's public investment in R&D has actually decreased since 2008 and in 2013 was recorded to account for just .72% of the state's GDP.[157] In a 2015 report on South African STI indicators, the National Advisory Council on Innovation (NACI), found that this declining R&D investment was visible in terms of "low growth" in several areas. Especially in engineering and technology publications, South Africa observed a decrease from 15.9% of world publications in 2007 to 15.03% in 2014.[158] However, the research of natural sciences continues to be an area of strength in South Africa, with consistent increases of publications since 2006.[159]

In regards to the quality of South African publications we look once more to citation data. While the citations of South African publications have increased steadily since 2005, some sectors have seen significant growth while others have not. Similar to the lack of uniformed publication growth, this is, in large part, the result of disorganization and a lack of funding. In

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[155] Ibid., 12.
[156] Ibid.
[157] "World Bank - Current GDP by Country." GDP (current US$) | Data. 2016. Accessed April 16, 2017.
[158] *NACI - South African science, technology and innovation indicators 2015*. Pretoria: National Advisory Council on Innovation and the Department of Arts, Culture, Science and Technology, 2015. 13.
[159] Ibid.

2014, citations of South African publications on Physical Sciences and Astronomy made up almost 7% of all citations in the field around the world.[160] This was an "extraordinary increase in citations relative to the global average."[161] Of course, many South African sectors have not continued to grow qualitatively.

In all, South Africa's Ten-Year Plan calls for the reinvigoration of universities and educational capacity. By committing to "growing the base of scientists and engineers"[162] South Africa hopes to develop knowledge workers who are capable of producing original research and meeting the needs of the country's changing economy. However, public spending has shrunk in recent years. South Africa's Ten-Year Plan calls for public R&D expenditure to account of 2% of the country's GDP by 2018.[163] However in 2008 public investment in R&D as a percentage of GDP was only .87% and in 2014 was measured at .76%.[164] As a result publications in many areas have not reflected any growth. However, focused funding, and the development of organizations that aim to grow human capital have allowed the total number of publications to grow.[165] This shows us that despite decreasing R&D funding, South Africa has found effective ways to develop human capital, and research within their country.

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[160] *NACI - South African science, technology and innovation indicators 2015*. Pretoria: National Advisory Council on Innovation and the Department of Arts, Culture, Science and Technology, 2015. 15.
[161] Ibid.
[162] DST - South Africa. Department of Science and Technology. *DST - Innovation Towards a Knowledge Based Economy Ten-Year Plan for South Africa*. Johannesburg : DST, 2007. 9.
[163] "OECD - Research and development (R&D) - Gross domestic spending on R&D - OECD Data." 2016.
[164] Ibid.
[165] *NACI - South African science, technology and innovation indicators 2015*. Pretoria: National Advisory Council on Innovation and the Department of Arts, Culture, Science and Technology, 2015. 15.

South Africa's citation data tells a similar story. Significant growth in some areas reflects the increasing quality of the country's publications. Like the publication data, citation rates in different fields show us that the state has focused organizational and fiscal efforts in strategic areas. Citation rates also give us some insight into the quality of the work being produced in South Africa. Clearly, the quality of work in some fields has progressed while others remain disconnected from the overall S&D research growth in the country. While one might presume that this would be a result of the natural course of growth for any state, South Africa has observed significantly less growth overall and almost no growth in some less strategic areas compared to China. This lack of uniformed growth of scientific and research capacity is concerning, as such a narrow base of basic research will not be able to supply the research and knowledge workers necessary for a state to effectively integrate into the knowledge economy.

South Africa's Ten-Year Plan calls for the aggressive advancement of education and research to foster innovation that will "contribute to rapid economic and social transformation."[166] While growth has not been as rapid as the DST might have hoped, South Africa's STI policy reflects an understanding of the importance of research and knowledge workers. Nonetheless, historical realities and political capacity challenge the nation's aspirations. The lack of research capacity in many universities as a result of apartheid, and the inability of the young government to efficiently implement funding strategies and policies have created uneven scientific development in South Africa.

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[166] DST - South Africa. Department of Science and Technology. *DST - Innovation Towards a Knowledge Based Economy Ten-Year Plan for South Africa*. Johannesburg : DST, 2007.

Technology, Innovation and Integration

South Africa's innovation progress can largely be characterized as disconnected. Like Brazil, South Africa has struggled to integrate innovation into the economy. Despite some scientific and research growth, South Africa's STI policy recognizes that innovation must be mobilized "in support of economic growth".[167] The Ten-Year plan proposes the development of "new creative funding mechanisms" to develop private partnerships, and close the financing gap for many firms.[168] In addition to financial challenges, South Africa's innovation also faces a lack of economic growth in many areas which has left private firms hesitant to invest in their own technology advancement. In an effort to incentivize the development of new technology, South Africa has developed a number of institutions and significant legislation that offers IP security and clarity. This section examines how the historical and political realities of the state have limited innovative growth in South Africa, as well as how the effective integration of new technologies has led to development in some sectors. We will also discuss the steps that the DST has taken, in pursuit of the goals set forth by the Ten-Year Plan, to integrate and push innovation forward in South Africa.

South Africa's "innovation chasm," or the gap between the rise of R&D and applied technologies, is something that is identified in the Ten-Year Plan as a "major weakness".[169] A major hurdle in the progress of South African innovation and its integration is a lack of substantial fiscal support, and past absence of any organization with the capacity to effectively

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[167] Ibid., 25.
[168] Ibid., 25.
[169] DST - South Africa. Department of Science and Technology. *DST - Innovation Towards a Knowledge Based Economy Ten-Year Plan for South Africa*. Johannesburg : DST, 2007. 25.

distribute such funding. This has been addressed primarily through the formation of the Technology Innovation Agency (TIA). The TIA has a number of broad objectives but is ultimately charged with facilitating funding innovation and promoting research-technology partnerships. Additionally, the TIA supports existing technology-based enterprises both public and private.[170] Like the overall public funding of R&D, the DST's allocation of funds to the TIA have fallen. In 2010 TIA's parliamentary grant amounted to over R544 million, and in 2016 was reported to be R385 million.[171] Consequently, the focussed spending on promoting innovation and integration has decreased. While the Ten-Year plan also calls for increases in private funding for innovation, many sectors lack the necessary resources. In some areas, "only 10 percent of [these] companies are estimated to be conducting innovative, cutting-edge R&D."[172] This type of applied research is necessary to drive innovation. Lack of human capital is also a challenge. The private firms tend to receive initial funding from state agencies but a lack of additional funding creates significant challenges for the continued private investment in applied technologies.

However, South Africa's innovation growth faces more than just financial struggles. apartheid has resulted in the "exclusion of a large fraction of the population from the formal economy".[173] These past societal divisions have also created crippling poverty in many areas of the country. Like its influence on the research capacity at some universities, this history of

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[170] Ibid., 26.
[171] *NACI - South African science, technology and innovation indicators 2015*. Pretoria: National Advisory Council on Innovation and the Department of Arts, Culture, Science and Technology, 2015. 15.
[172] DST - South Africa. Department of Science and Technology. *DST - Innovation Towards a Knowledge Based Economy Ten-Year Plan for South Africa*. Johannesburg : DST, 2007. 27.
[173] "South Africa STI Outlook Profile." Innovation Policy Platform. January 01, 2016. Accessed April 16, 2017.

division has affected South Africa's attempts to develop and integrate innovation. This is apparent in the lack of innovative production in many fields. The situation is only exacerbated by the lack of diversity in South Africa's economy. Many features of South African geography have allowed certain sectors to grow. South Africa's mining industry and the exportation of minerals provides are examples of growing sectors that have progressed immensely. Many private firms have made substantial investments into the development of technology in these areas. Conversely, other sectors such as agriculture, food processing, and manufacturing have not observed significant growth. In 2014 the Organization for Economic Cooperation and Development (OECD) published a report which measured the revealed technology advantage (RTA) of various sectors within South Africa. The report found that South Africa, while holding potential in several sectors, only observed significant RTA ratings in environmental technology and thermal processes and apparatus.[174] This lack of capacity effectively means that many areas have not contributed significantly to the development of new technologies. With direct funding from the state decreasing, South Africa relies heavily on private firms to develop new technologies. However, many firms simply lack the capacity to invest in, and develop, applied technology.

In an effort to encourage private investment into technology and innovation, the Ten-Year Plan also calls for the development of an intellectual property management office to

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[174] *NACI - South African science, technology and innovation indicators 2015*. Pretoria: National Advisory Council on Innovation and the Department of Arts, Culture, Science and Technology, 2015. 36.

"enhance the protection of intellectual property rights".[175] While most internationally utilized patents are awarded by the United States Patent and Trademark Office (USTPO), most countries have their own patent authorities.[176] However, South African protection of intellectual property (IP) has been historically weak. A lack of IP protection acts as a disincentive for firms to develop new technology in South Africa. In 2008 South Africa founded the Companies and Intellectual Property Commission (CIPC), which is now the governing body that oversees all IP protection and enforcement in the country.[177] The CIPC emerged following the enactment of the Companies Act of 2008, which outlined a the reorganization of the corporate governance with the vision that "company law should promote the competitiveness and development of the South African economy."[178] This act and the creation of CIPC represents South Africa's desire to show domestic and foreign firms that their country is a secure hub to develop applied technologies.

Like Brazil and China, South Africa also offers a series of tax incentives to accelerate innovation. Amongst these is a 150% deduction for operation costs of R&D.[179] This incentive allows firms approved by the DST to deduct the cost of actually operating a research facility.[180] This policy is different from Brazil's strategy, which of offers tax deductions for R&D

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[175] DST - South Africa. Department of Science and Technology. *DST - Innovation Towards a Knowledge Based Economy Ten-Year Plan for South Africa*. Johannesburg : DST, 2007. 26.
[176] *NACI - South African science, technology and innovation indicators 2015*. Pretoria: National Advisory Council on Innovation and the Department of Arts, Culture, Science and Technology, 2015. 36.
[177] "DTI - Companies and Intellectual Property Comission." Companies and Intellectual Property Commission (CIPC). 2015. Accessed April 16, 2017.
[178] Ibid.
[179] Deloitte - "2015 Global Survey of R&D Incentives." Deloitte . October 2015. Accessed March 2017. 48.
[180] Ibid.

equipment. However, this incentive acts in a similar way, aiming to incentivize domestic and foreign investment in R&D. It is also worth mentioning that the firms eligible for these deductions are only those conducting "investigative or systematic experimental activities" that lead to the "creating or invention" of designs in several fields. In this way South Africa is focusing R&D efforts in applied and experimental fields. Some scholars believe that these efforts are indicative of South Africa's desire to spark development comparable to the level that the state *perceives* it should be, as opposed to developing at a more realistic rate.[181] This lack of intention to develop basic science and R&D in existing sectors only exacerbates the innovation chasm in the country. Nevertheless, the R&D tax incentives offered in South Africa are a facet of a larger strategy to encourage the development of new technology in the country. Similar incentives can be found in both China and Brazil.

To measure the effectiveness of South Africa's efforts to develop innovation capacity and integration, we will look to patent statistics. With the exception of a slight decline between 2014 and 2015, South Africa has shown a gradual increase in awarded patents.[182] However, the percentage of USPTO patents granted South African firms has decreased since 2009.[183]. Essentially, this means that the growth of innovation witnessed in South Africa in the past ten years has not been on par with global growth. Additionally, the "innovation chasm" in South

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[181] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives: innovation systems and policies*. London: Anthem, 2011.
[182] *NACI - South African science, technology and innovation indicators 2015*. Pretoria: National Advisory Council on Innovation and the Department of Arts, Culture, Science and Technology, 2015. 33.
[183] *NACI - South African science, technology and innovation indicators 2015*. Pretoria: National Advisory Council on Innovation and the Department of Arts, Culture, Science and Technology, 2015. 33.

Africa is also evident in the lack of patent growth relative to increases in GDP. Like other BRICS countries, South Africa has witnessed substantial economic growth in the past two decades. Between 2002 and 2011, the country's GDP nearly quadrupled.[184] However, during the same period, total IP filings only increased from 1,661 to 1,763.[185] Patent applications did increase slightly after this period but fell, like the country's GDP between 2013 and 2015.[186] This lack of innovative growth, despite growing economic strength, is a reflection of the challenges that South Africa's STI policy faces today. A lack of effective state support and knowledge workers combined with the limited capacity of firms has largely blocked innovative growth in South Africa. These patents statistics display the reality of the country's "innovation chasm."

Despite many setbacks concerning innovation and innovation integration, some sectors display how effective integration of innovation can boost economic growth and state development. Like Brazil, the state has developed several national "champion firms." The South African Coal, Oil and Gas Corporation (Sasol) is one such organization. Founded in 1950 by the National Party government, Sasol was created to ensure greater fuel self-sufficiency for the country.[187] While the innovative capabilities of South Africa were greatly hindered by political dysfunction and restructuring, Sasol "has played an important role in upgrading the scientific

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[184] "World Bank - Current GDP by Country." GDP (current US$) | Data. 2016. Accessed April 16, 2017.
[185] "WIPO: Statistical Country Profiles." WIPO - World Intellectual Property Organization. 2016. Accessed April 16, 2017.
[186] Ibid.
[187] Lundvall, Bengt-Ake; Joseph, K.J; Chaminade, Cristina; Vang, Jan. *Handbook of innovation systems and developing countries: building domestic capabilities in a global setting*. Edward Elgar. Cheltenham, UK. 2011.

capabilities in the country."[188] Throughout its growth Sasol "continued to benefit from government support."[189] Now, Sasol is a world leader in oil-from-gas technologies and synthetic fuel technologies and is the South Africa's largest corporate taxpayer. Between 2010 and 2014 Sasol's technology division was granted the most patents of any South African institution, accounting for more patents than the next three institutions combined.[190] The multinational corporation pays over R8 billion in taxes annually.[191] More importantly, Sasol plays a major role in further innovation capacity in South Africa. Over the course of ten years the Sasol's Global Foundation (SGF) has developed a partnership program with South African Universities to "improve research and teaching facilities in STEM disciplines."[192] Sasol has invested over R250 million into research undertaken at 11 universities in the country.[193] Additionally, Sasol directly invests in "small and medium" firms engaged in innovation and technology development.[194]

The growth of Sasol amidst the struggles of many areas of South African innovation reminds us of how direct state support can further innovation integration. Sasol has played a significant role in supporting university research, and developing smaller research and innovation firms. Furthermore, Sasol provides thousands of jobs and millions in tax revenue for the state. While this type of growth cannot be expected from all sectors, Sasol's success represents many of the aspirations of the Ten-Year Plan, and potential growth that can result

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[188] Ibid., 143.
[189] Ibid., 257.
[190] *NACI - South African science, technology and innovation indicators*, 2015. 36.
[191] Donnelly, Lynley. "Sasol the tax cow." The M&G Online. 2008. Accessed April 16, 2017.
[192] SASOL. *Sustainable Development Information 2015, Delivering Social Value*. 2015. 7.
[193] Ibid., 8.
[194] Ibid., 7.

from the state's direct support of STI development.

Reflecting on South African STI Policy

Of the rapidly growing BRICS states that we have examined, South Africa's STI growth is undoubtedly the most underwhelming. Despite admirable efforts to move their economy towards a knowledge-driven society, South Africa faces many challenges. Apartheid left many public institutions with a lack of capacity to further the country's new STI-driven agenda. Additionally, South Africa's young economy has been unable, on many fronts, to successfully integrate policy that can effectively move the country towards the goals set forth by the Ten-Year Plan.

Many believe that these challenges make South Africa a strange addition to the BRICS group. South Africa's GDP per capita and nominal GDP are both, by far, the lowest of the BRICS countries. However, South Africa's influence within the African continent is undeniable. South Africa accounts for over 30 percent of the entire continent's GDP, and is second only to Nigeria in terms of African GDP.[195] Regardless of the state's relative strength within the BRICS, South Africa is an excellent example of how context should be taken into account when a state implements STI policy.

There is little doubt that South Africa has recognized the importance of STI policy as a core facet of state development. The Ten-Year Plan is an aggressive, perhaps overambitious, strategy to completely reshape the country's STI framework. The Ten-Year Plan outlines the

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[195] "World Bank - Current GDP by Country." GDP (current US$) | Data. 2016.

development of an NSI that is dedicated to readying South Africa to integrate into the knowledge economy. South Africa has implemented a number of policies that resemble strategies we have seen in China and Brazil. That being said, these policies have not generated the same results. Thus, our analysis of South African STI policy is especially useful in furthering our understanding of how historical and political contexts can affect STI growth.

Like our analysis of China and Brazil, our exploration of the Ten-Year Plan and STI in South Africa has revealed a renewed focus on STI development. Additionally, the contextual aspects of South Africa provide an excellent addition to our perspective of varying state realities and how they affect STI growth. While historical and political factors played a role in Chinese and Brazil STI strategy, this section shows a severe case that completes our comparative analysis. Segments of the Ten-Year Plan seek to address STI issues that are specific to South Africa. However, we can conclude that this aggressive strategy largely ignores many of the political and historical realities of the country.

This analysis of South African STI policy echoes the findings of Glenda Kruss and Jo Lorentzen. They surmise that the country's "policy that was adopted did not adequately take into account the historical and contextual conditions of South Africa as a latecomer society."[196] Consequently South Africa's Ten-Year Plan, while reflecting the growing importance of STI, has resulted in a lack of STI growth.

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[196] Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives: innovation systems and policies*. London: Anthem, 2011. 163.

Conclusion

This exploration of STI and STI policy provides two conclusions. First, we find that developing states, such as the BRICS, now understand STI growth as an essential condition of economic growth and state development in the modern international community. Of course economic growth has been long the priority of many developing and developed countries. The Developmental state theory reflects this sentiment, but also highlights the importance of state-intervention and the implementation of strategic industrial policies if states are to observe rapid economic growth. However, under the impetus of globalization, states have begun to perceive the most effective ways to achieve this growth differently than they have in the past. States now perceive the demands of the knowledge economy as increasingly important. The development of STI capacity lies at the heart of these demands. However, these states also seek to integrate into the global economy through STI growth by signaling their competitive prowess by way of STI success. The theory of the competition state engages how the state can create policies that make the state more effective in this new global environment. Essentially we can understand STI policy as a way for developing states to foster competitive growth in the modern global economy. These competition states thus prioritize methods of state intervention and influence that further the type of development necessary to compete as a growing, modern, international power that is able to draw and to develop the critical resources of knowledge and technology. In this way, China, Brazil and South Africa have all sought to further their economic and international status by the rapid development of STI capacity and sophisticated NSI. Furthermore, it is clear that, in this case, globalization has not resulted in the decreased

significance of the state. In fact, the ability of the state to create and implement effective STI policy has an increasing important role in economic growth.

This first conclusion shows us that the role of the state is not in decline. In actuality, this research shows that the ability of the state to implement effective strategies and policies is fundamental in furthering economic, and state development. This is displayed by integration of major STI policies into the development strategies of China, Brazil and South Africa. These STI plans explicitly address these states' hope that STI growth will act as the primary driver of overall state development. In this way, state development today is largely determined by the state's ability to implement STI policy, is critical to modern economic growth and competitiveness. Our discussion of the NSI and the knowledge economy shows us that STI is now of paramount importance. In many ways a country's STI capacity is not only a method used to spark economic growth, but also serves as a way for countries to indicate their international competitiveness. Countries that present strong publication and patent numbers are likely to attract firms that develop science and new technologies. This research shows that both the strength of the state and the development of STI capacity are crucial to building modern economic and overall state development.

Secondly, the comparative analysis of modern STI policies indicates that the ability of STI capacity to enable a state to integrate and remain competitive in the global economy is shaped and constrained by the political realities and institutional legacies of each state. The historical and political realities of any given state shape which policies are implemented and which strategies are effective. The comparative analysis of China, Brazil and South Africa shows

us how historical and political factors affect the implementation of STI policy. China's history of developing and integrating thorough policies into industry is reflected in the efficient development of China's STI capacity. The development of organizations that are able to effectively implement the MLP, in addition to the organized distribution of funding to strategic areas, has created significant STI growth and ensuing economic growth. Brazil's recognition of their lack innovative integration has led to the development of a strategic STI policy designed to bolster technological integration into industry. However, because of the state's inability to effectively monitor, measure, and oversee these strategies we have seen a lack of STI growth. Brazil has clearly recognized areas that require strategic state intervention and support, but lacks the capacity and focused funding to meet their goals of substantial STI growth. In the case of Brazil, it is clear that a state must recognize their limitations to effectively grow STI policy. However, in South Africa, we find an STI policy that largely ignores many of the realities and limitations of the state. A young government, and a history of apartheid have left the state divided and unable to implement strong policy. South Africa's attempt to "leapfrog" directly into the modern global economy by way of STI growth has been hindered by these realities. It is clear that countries must seek the development of STI capacity in a way that effectively utilizes existing state strengths and recognizes weaknesses. We find that the successful development and integration of STI can result in significant strategic economic growth. However, the unsuccessful development of STI can result in stunted economic growth and an ensuing lack of societal growth

Figure 1

	R&D as % of GDP 2003[197]	R&D as % of GDP 2012	GDP (USD) 2003	GDP (USD) 2012	Total Patent Filings 2003[198]	Total Patent Filings 2012
China	1.12	1.92	1.66 Trillion	8.56 Trillion	58,757	561,408
Brazil	0.99	1.15	558.32 Billion	2.46 Trillion	4,451	6,603
South Africa	0.76	0.73	175.25 Billion	396.34 Billion	1,540	1,688

[197] "World Bank - Current GDP by Country." GDP (current US$) | Data. 2016.

[198] "WIPO: Statistical Country Profiles." WIPO - World Intellectual Property Organization. 2016.

Works Cited

Amsden, Alice H. *Asia's next giant: South Korea and late industrialization.* New York: Oxford University Press, 1992.

Bernardes, Américo Tristão, and Eduardo Da Motta E Albuquerque. "Cross-over, thresholds, and interactions between science and technology: lessons for less-developed countries." *Research Policy* 32, no. 5 (2003): 865-85. doi:10.1016/s0048-7333(02)00089-6.

Broad, Eleanor , Ben Choi, Daniel Drum, and Sergio Lagunes. "Embraer's Creation of Value for Shareholders and the Brazilian Economy." *Chazen Web Journal of International Business* Winter (2005): 1-19.

Cao, Cong, Richard P. Suttmeier, and Denis Fred Simon. "China's 15-year science and technology plan." *Physics Today* 59, no. 12 (2006): 38-43. doi:10.1063/1.2435680.

Cassiolato, José Eduardo., and Virgínia Vitorino. *BRICS and development alternatives: innovation systems and policies*. London: Anthem, 2011.

Cerny, Philip G. "Paradoxes of the Competition State: The Dynamics of Political Globalization." *Government and Opposition* 32, no. 02 (1997): 251-74. doi:10.1111/j.1477-7053.1997.tb00161.x.

"China Statistical Yearbook 2016." China Statistical Yearbook-2016. Accessed April 16, 2017. http://www.stats.gov.cn/tjsj/ndsj/2016/indexeh.htm.

"China to strengthen basic research." People's Republic of China Government Website. Accessed April 16, 2017. http://www.gov.cn/english/2006-02/09/content_183726.htm.

DACST- South Africa. Department of Arts, Culture, Science and Technology. *DACST - White Paper on Science and Technology: Preparing for the 21st Century*. 1996.

Deloitte - "2015 Global Survey of R&D Incentives." Deloitte . October 2015. Accessed March 2017. https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/tax/deloitte-nl-tax-global-survey-r-and-d-incentives-2015.pdf.

Dias, Rafael, and Milena Serafim. "Science and technology policy in Brazil: An analysis of the

recent period." *2011 Atlanta Conference on Science and Innovation Policy*, 2011. doi:10.1109/acsip.2011.6064468.

Donnelly, Lynley. "Sasol the tax cow." The M&G Online. 2008. Accessed April 16, 2017. https://mg.co.za/article/2008-07-04-sasol-the-tax-cow.

DST - South Africa. Department of Science and Technology. *DST - Innovation Towards a Knowledge Based Economy Ten-Year Plan for South Africa*. Johannesburg : DST, 2007.

DST - South Africa. Department of Science and Technology. *DST Strategic Plan for the Fiscal Years 2011 - 2016*. 2011.

"DTI - Companies and Intellectual Property Comission." Companies and Intellectual Property Commission (CIPC). 2015. Accessed April 16, 2017. https://www.thedti.gov.za/agencies/cipc.jsp.

"Economic Normal Development and Transformation is Continuing ." National Bureau of Statistics of the People's Republic of China. 2016. Accessed April 16, 2017. http://www.stats.gov.cn/tjsj/sjjd/201605/t20160531_1362661.html.

"Embrapa - Who We Are." Embrapa.Brazil. 2010. Accessed April 16, 2017. https://www.embrapa.br/.

Evans, Mark. "Neoliberalism and Policy Transfer in the British Competition State: the Case of Welfare Reform." *Internalizing Globalization*, 2005, 69-89. doi:10.1057/9780230524439_4.

Evans, Peter B. *Embedded autonomy: states and industrial transformation*. Chichester: Princeton University Press, 1995.

Fagerberg, Jan. "Technology and international differences in growth rates." *Journal of economic Literature* 32, no. 3 (1994): 1147-1175.

Freeman, Chris. "The 'National System of Innovation' in historical perspective." *Cambridge Journal of Economics* 19, no. 11 (1995): 5-24. doi:10.1093/oxfordjournals.cje.a035309.

Glosny, Michael A. "China and the BRICs: A Real (but Limited) Partnership in a Unipolar

World." *Polity* 42, no. 1 (2010): 100-29. doi:10.1057/pol.2009.14.

"IDA: Innovation Policies of Brazil." *Institute for Defense Analyses* , September 2013. https://www.ida.org/idamedia/Corporate/Files/Publications/STPIPubs/2014/ida-p-5039.ashx.

IPP - "South Africa STI Outlook Profile." Innovation Policy Platform. January 01, 2016. Accessed April 16, 2017. https://www.innovationpolicyplatform.org/content/south-africa.

Jaffe, Adam B., and Manuel Trajtenberg. *Patents, citations and innovations: a window on the knowledge economy*. Cambridge, MA: MIT, 2005.

Jain, Shuhash C. *Emerging economies and the transformation of international business: Brazil, Russia, India and China (BRICs)*. Cheltenham: Elgar, 2006.

Johnson, Chalmers A. *MITI and the Japanese miracle: the growth of industrial policy: 1925-1975*. Stanford: Stanford University Press, 2012.

Lundvall, Bengt-Åke. *National systems of innovation: toward a theory of innovation and interactive learning*. London: Anthem Press, 1992.

Lundvall, Bengt-Ake; Joseph, K.J; Chaminade, Cristina; Vang, Jan. *Handbook of innovation systems and developing countries: building domestic capabilities in a global setting*. Edward Elgar. Cheltenham, UK. 2011.

"MOST: Chinese Science and Technology Statistics, 2006 ." Ministry of Science and Technology of the People's Republic of China. Accessed April 16, 2017. http://www.most.gov.cn/eng/.

Motta, Tonaldo. "Eco-Innovation in Brazil." Proceedings of Global Forum on Environment on Eco-Innovation OECD, Paris . 2009.

MST "Ministry of Science and Technology ." Ministry of Science, Technology Innovation and Communications Brazil . 2012. Accessed April 16, 2017. http://www.mcti.gov.br/.

NACI - South African science, technology and innovation indicators 2015. Pretoria: National

Advisory Council on Innovation and the Department of Arts, Culture, Science and Technology, 2015.

Nelson, Richard R. *National innovation systems: a comparative analysis*. New York (N.Y.): Oxford University Press, 1993.

"OECD - Research and development (R&D) - Gross domestic spending on R&D - OECD Data." OECD Data. 2016. Accessed April 16, 2017.

O'Neill, Jim. *Building better global economic BRICs*. New York: Goldman, Sachs & Co., 2001.

Öniş, Ziya. "The Logic of the Developmental State." *Comparative Politics* 24, no. 1 (1991): 109-26.

Ohmae, Kenichi. *The end of the nation state: the rise of regional economies*. New York: Free, 2010.

Reich, Robert. "The work of nations: Preparing ourselves for twenty-first century capitalism." *New York: Alfred Knopf* (1991).

Reid, Michael. *Brazil: The Troubled Rise of a Global Power*. New Haven: Yale UP, 2015.

Ricz, Judit. "Developmental State in Brazil: past present and future." *Federalismi.it*, October 29, 2014, 2-20. http://real.mtak.hu/18391/1/Ricz%20J._Developmental...Federalismi.it.pdf.

Ritzer, George, and Paul Dean. *Globalization: a basic text*. Oxford: Wiley-Blackwell, 2015.

SASOL. *Sustainable Development Information 2015, Delivering Social Value*. 2015.

"SJR: Scimago Journal and Country Rank ." SJR - International Science Ranking. Accessed April 16, 2017. http://www.scimagojr.com/countryrank.php.

Soete, Luc. "2 1 Catching up in technology: entry barriers and Windows of opportunity." (1988).

Stubbs, Richard. "What ever happened to the East Asian Developmental State? The unfolding debate." *The Pacific Review* 22, no. 1 (2009): 1-22. doi:10.1080/09512740802650971.

"Technology Statistical Data." National Bureau of Statistics of China. Accessed April 16, 2017. http://www.stats.gov.cn/english/.

UNESCO science report: towards 2030. Paris: UNESCO, 2015.

"UNESCO Science Report 2010." *United Nations Educational, Scientific and Cultural Organization* , 2010. Accessed April 16, 2017. http://unesdoc.unesco.org/images/0018/001899/189958e.pdf.

Waters, Malcolm. "globalization Routledge." *London and New York* 94 (1995): 123-157.

Williams, Michelle. *End of the developmental state?* Place of publication not identified: Routledge, 2015.

"WIPO: Statistical Country Profiles." WIPO - World Intellectual Property Organization. 2016. Accessed April 16, 2017. http://www.wipo.int/.

Williams , Sophie. "China develops new supercomputer that is 10 TIMES faster than the current quickest machine in the world ." Daily Mail Online. November 02, 2016. Accessed April 16, 2017.

Wong, Chan-Yuan, and Lili Wang. "Trajectories of science and technology and their co-evolution in BRICS: Insights from publication and patent analysis." *Journal of Informetrics* 9, no. 1 (2015): 90-101. doi:10.1016/j.joi.2014.11.006.

Woo-Cumings, Meredith. *The developmental state*. Ithaca (N.Y.): Cornell university press, 1999.

"World Bank - Current GDP by Country." GDP (current US$) | Data. 2016. Accessed April 16, 2017. http://data.worldbank.org/indicator/NY.GDP.MKTP.CD.

"Xi sets targets for China's science, technology mastery." China Association for Science and Technology. Accessed April 16, 2017. http://english.cast.org.cn/n1181872/n1182018/17226678.html.

Zhou, Ping, and Loet Leydesdorff. "The emergence of China as a leading nation in science."

Research Policy 35, no. 1 (February 2006): 83-104. doi:10.1016/j.respol.2005.08.006.