# The accidental agro-power

**The Accidental Agro-Power:**

**Constructing Comparative Advantage in Brazil ***

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*Abstract:* Brazil has emerged as an agro-export powerhouse: from being a net-agricultural importer and food aid recipient as recently as the 1960s and 1970s, it has now become the world's third largest agricultural exporter, after the US and EU. What is more, Brazil's new role as a major agricultural trader has provided an important foundation for its enhanced status and influence in global economic governance, as an emerging power and one of the BRICS. This paper analyzes how such a remarkable transformation was brought about. I argue that Brazil's emergence as an agricultural powerhouse was the result not of its natural factor endowments, but extensive intervention on the part of the Brazilian state that had the effect of constructing a new comparative advantage. This transformation was propelled by state-driven innovation and related policies that opened up massive new areas of the country to agriculture, enabled it to shift to producing goods in direct competition with the world's dominant agricultural exporters, and generated significant gains in productivity and competitiveness. The irony is that the intention of these policies, initiated in the 1970s, was to foster industrial development in Brazil as part of its import-substitution industrialization program, yet they wound up having precisely the opposite effect – transforming Brazil into one of the world's dominant agricultural powers.

*Keywords:* Brazil, agriculture, emerging economies, emerging powers, trade, comparative advantage

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## Introduction

Since the 1970s, Brazil has been transformed from a net-agricultural importer into an agro-export powerhouse. It is now one of the largest and most competitive agricultural producers in the world and a serious threat to the global market dominance of the world's leading agricultural exporters, the US and EU. The rapid expansion of its agribusiness exports has contributed to fostering macroeconomic stability, fueling high rates of economic growth and boosting government revenues, which have, in turn, made possible redistributive policies that have produced significant gains in reducing poverty and inequality (Ioris Forthcoming; Spolador and Roe 2013).

Brazil's emergence as a major agricultural trader has also contributed to its status as an emerging power and enabled it to secure a more prominent role in global governance (Armijo and Burges 2010; Hurrell 2010). Brazil's rise has been most striking at the World Trade Organization (WTO), where it joined the elite inner-circle of decision-making and played a central role in the Doha Round (Grant 2007; Hopewell 2013; Mahrenbach 2013). Propelled by the rise of its agro-export sector, Brazil emerged as a vocal advocate of agricultural trade liberalization, winning two landmark trade disputes against the US and EU and leading a major developing country coalition, the G20, in challenging rich country subsidies (Clapp 2006; Narlikar and Tussie 2004). Brazil's activism was ground-breaking and had profound implications: by turning the tables and seizing the offensive vis-à-vis the traditional powers, it helped bring an end to the longstanding dominance of the US and EU and put their trade policies at the center of the Doha Round (Hopewell 2015).

Beyond the WTO, Brazil secured a seat in the G20 Leader's Summit, comprised of the major developed and developing economies, when it replaced the G8 as the primary forum for

international economic cooperation (Cooper 2010; Schirm 2013). Brazil is a founding member of the BRICS Forum, as well as the New Development Bank, an alternative and rival to the Western-dominated World Bank (Chin 2014). Brazil has also played a prominent role in the international climate change negotiations (Hochstetler and Viola 2012). And, in a further sign of its clout, Brazilian officials have been chosen to head key international organizations: José Graziano da Silva, the architect of Brazil's Zero Hunger program, was elected Director-General of the UN Food and Agriculture Organization in 2012 and Roberto Azevêdo, previously Brazil's Ambassador and Chief Negotiator, was appointed WTO Director-General in 2013.

This paper analyzes the transformation of Brazilian agriculture that has propelled its rise as an agricultural power. I argue that Brazil's agribusiness boom was the result not of natural but constructed comparative advantage. Extensive state intervention played a fundamental role in altering Brazil's position in the global economy and turning it into a world-leading agricultural exporter. Brazil's experience thus defies the assumptions of traditional models of development in the global political economy: contrary to the principles of neoliberalism, Brazil's comparative advantage has been successfully reshaped as the result of active intervention by the Brazilian state; yet, contrary to the principles of developmental state theory, this move has been in the direction not of industry but agriculture. Specifically, this has involved the construction of a new comparative advantage, not in the tropical products typically exported by developing countries, but in the bulk crops and livestock that made temperate developed countries the world's dominant agricultural powers.

The reason that state intervention was critical to the development of Brazilian agribusiness is that, contrary to what has become the conventional wisdom, Brazil was *not* naturally suited to becoming a major agricultural exporter. With one of the largest supplies of

land in the world, Brazil's natural factor endowments would appear highly conducive to agricultural production. But, in fact, due to the nature of its tropical soil and climate, much of this land was inhospitable for agriculture. It took extensive state intervention to transform the country's massive endowment of land into an effective resource for commercial agriculture. Brazil's natural factor endowments alone were insufficient. Instead, Brazil's emergence as an agricultural powerhouse was propelled by state-driven innovation and related policies that transformed a large part of the country that was previously considered an agricultural wasteland into one of the most productive agricultural regions in the world, made it possible to grow temperate crops in its tropical climate, and dramatically increased the efficiency and competitiveness of Brazilian agriculture.

Ironically, however, I show that Brazil's transformation into an agro-power was an accidental outcome of policies intended to have precisely the *opposite* effect – specifically, it originated in a set of policies born in the 1970s as part of a project of import-substitution industrialization (ISI) intended to move Brazil away from dependence on agricultural exports and foster the industrialization of its economy. The argument presented here thus departs from conventional accounts of Brazil's agribusiness boom, which is most often heralded as the result of its economic reforms and liberalization. This example from an article in *Foreign Affairs* is typical: "the secret of Brazil's current success," it asserts, lies in its "market-friendly economic policies" (De Onis 2008: 110). While acknowledging the role of technological innovation and (private) investment, the article makes no mention of the state's involvement or the fact that its key policies and investments stemmed from the ISI era. Instead, it presents a highly selective reading of Brazil's recent economic history that serves to confirm the dominant market-oriented economic paradigm, within which ISI is commonly dismissed as a failure (Buscaglia and Long

1997; Shafaeddin 2012), precisely due to its purported inability to generate technological advance and competitiveness (Meyer-Stamer 2005). Indeed, among mainstream economists, ISI is effectively "seen as a four-letter word" (Vernengo 2012). In contrast to the prevailing view, however, I contend that, in fact, Brazil's agribusiness boom had unexpected roots in its earlier ISI project.

**Comparative Advantage, Agriculture and Development in the Global Political Economy**

The issue of comparative advantage lies at the center of longstanding debates in international political economy regarding the relationship between trade and development. As the prevailing economic paradigm since the 1980s, neoliberalism has preached with near-religious zeal the power of free markets to bring efficiency, growth and prosperity (Blyth 2002). Rooted in the trade theory of Adam Smith and David Ricardo, at the heart of economic liberalism is the theory of comparative advantage, which states that a country will maximize its economic welfare by specializing in producing and exporting goods in which it has a relative advantage compared to other states (Ho 2010). In other words, a country should trade based on its natural factor endowments and inherent comparative advantage. Any state intervention to try to alter a country's comparative advantage would only be counter-productive, creating inefficiencies that impede growth (Bhagwati 2004). According to the "Washington Consensus" propagated by the multilateral economic institutions, the solution to underdevelopment was for countries to liberalize and open their economies, remove state intervention and "free" markets to facilitate the efficient movement of goods and capital (McMichael 2012).[1]

[1] Neoliberalism nonetheless embodies significant contradictions (Peck 2010, Schmidt and Thatcher 2013). Rather than being genuinely non-interventionist, neoliberalism has in practice involved not deregulation but re-regulation – that is, specific forms of intervention designed to promote the interests of private capital (Fine 2012; Vogel 1996).

Notwithstanding moderate tinkering, this neoliberal perspective remains largely intact as the dominant view of trade and development; as Robert Wade (2010: 159) states, "no alternative policy paradigm to neoliberalism has yet attracted wide support." When confronted with the East Asian miracle, for example, which confounded the expectations of laissez-faire, the World Bank acknowledged the role of selective state intervention, but nonetheless maintained that the success of the Asian tigers was primarily due to "market friendly" policies and that, if industrial policy worked, it was only because firms were subject to competitive disciplines that mimicked those of the market (World Bank 1993). Retaining a deep skepticism towards the state, mainstream economic beliefs continue to have at their core "the proposition that 'government failure is generally worse than market failure', which supports the default policy setting of 'more free market' in most countries most of the time" (Wade 2010).

In contrast to the neoliberal orthodoxy, developmental state theory offers a markedly different diagnosis of the causes of, and prescription for, underdevelopment. It challenges the fundamental premise of liberal trade theory: that countries should trade based on their natural factor endowments and resulting comparative advantage. Critical approaches (such as structuralism, dependency theory, and world systems theory) contend that the prospects for poor countries to develop are blocked by their dependence on primary product exports at comparatively low and highly volatile prices, which, combined with their reliance on imports of higher-value manufactured goods from advanced-industrialized states, locks developing countries into a system of unequal exchange (Ho 2010). With the export of commodities identified as a barrier to economic prosperity and manufacturing viewed as the cornerstone of development (Gereffi 1989), it is argued that underdeveloped countries need to industrialize in

order to be released from "the straitjacket of agrarian, pastoral, and mining production" (Cardoso 2009: 297).

Developmental state theory thus advocates a highly interventionist state to foster import substitution or export-oriented industrialization (Heller, Rueschemeyer and Snyder 2009). This includes, for example, the selective use of trade and investment restrictions and/or incentives to foster new industries and encourage technology transfer and industrial upgrading. The ISI variant of the developmental state is credited with the successful industrialization achieved by some developing countries, especially in Latin America, during the 1950s-1970s, while the export-oriented variant propelled the rapid growth of the East Asian newly industrialized countries (NICs), such as Korea, Singapore, Taiwan and Hong Kong, in the 1960s-80s (Amsden 1989; Evans 1979; Wade 1990). The notion of *constructed* comparative advantage at the heart of developmental state theory maintains that states can and should purposefully work to shape their international specialization; the role of the developmental state is to actively reengineer a country's comparative advantage from the production of primary products to higher-value manufactured goods.

Although theories of trade have grown increasingly complex, incorporating additional dynamics beyond differences in factor endowments and comparative advantage – including economies of scale, firm agglomeration and inter-firm production networks (Gereffi 1999; Krugman 1996) – these still remain central to contemporary debates about trade and development in the global political economy. Most recently, comparative advantage has been at core of debates surrounding the "new structural economics" launched by Justin Lin when Chief Economist of the World Bank. In a departure from the original Washington Consensus, Lin argues that industrial upgrading and technological advance are critical for economic

development but will not happen through market forces alone and require state intervention. Lin contends that development is best promoted by a "facilitating state" – "a state that facilitates the private sector's ability to exploit the country's comparative advantage," by subsidizing innovation and investing in human capital, infrastructure, and financial and legal institutions (Lin and Chang 2009: 484). Yet, according to Lin, "the key is to make use of the country's current comparative advantage" – he rejects the notion that the state has a role to play in creating comparative advantage, arguing that "comparative-advantage-defying" approaches are costly and counterproductive and likely to produce "sickly infant industries that never mature" (Lin and Chang 2009: 484, 487). Critics, however, contest the claim that a developing country can catch up with the more advanced economies by following the dictates of its existing endowment structure and comparative advantage (Fine and Van Waeyenberge 2013; Wade 2010). As Ha-Joon Chang argues, it is necessary "to defy comparative advantage if a country is going to enter new industries and upgrade its industrial structure" (Lin and Chang 2009: 492).

Broadly speaking, perspectives on trade and development thus remain split between, on one pole, the view that a country should embrace its existing comparative advantage and specialize in exporting products where it is naturally competitive due to its factor endowments and, on the other, the view that a highly interventionist state is needed to transform a country's comparative advantage and foster the development of manufacturing industries. In the analysis that follows, I show that Brazil's path of state-sponsored agricultural development departs from the principles and expectations of both perspectives. Brazil did not emerge as an agro-export powerhouse by relying simply on its natural factor endowments and the magic of the market. Instead, it needed state intervention to construct its comparative advantage, which has, in turn, provided the foundation for its new economic and political clout on the international stage.

Occurring alongside and shaped by real-world policy developments in Brazil and elsewhere, a new strand of development thinking – "neodevelopmentalism" – has emerged since the 2000s. If the Washington Consensus and developmentalism are ideal types that constitute the extreme ends of the "liberal-statist policy spectrum," neodevelopmentalism is a hybrid that falls somewhere in the middle (Ban 2012: 302). Neodevelopmentalism combines neoliberal macroeconomic policies and export-oriented growth with renewed emphasis on industrial policy and redistributive measures (Morais and Saad-Filho 2012). There is no manifest consensus among neodevelopmentalists on whether industrial policy should be comparative advantage conforming or comparative advantage defying, and Cornell Ban (2012) shows that Brazil's contemporary strategy combines elements of both. Crucially, though, Brazil's recent neodevelopmentalism has been significantly buttressed and enabled by the strong performance of its agribusiness sector. While the economic turmoil of the 1980s and early-1990s (debt crisis, acute recession, hyperinflation, capital flight) created an unfavorable climate that undermined the Brazilian state's ability to effectively pursue developmental policy goals, it was only with more favorable economic conditions in the 2000s that the state was able to pursue a strategy of "renewed developmentalism" with an ever-growing range of industrial policies to enhance competitiveness and innovation priorities (Hochstetler and Montero 2013). Through its substantial contribution to macroeconomic stability, economic growth and fiscal revenues, the massive expansion of agribusiness exports thus played a critical role in providing the foundation for Brazil's neodevelopmentalist model (Spolador and Roe 2013). By the time of its neodevelopmentalist turn, Brazil did indeed have an "inherited" comparative advantage in industrial agriculture; but, as I will demonstrate, this was new and the direct result of earlier state interventions. If "the BRICs' reassertion of the role of the state in development is one of the

most consequential events of the global economy" (Ban and Blyth 2013: 250), then understanding the origins of Brazil's agribusiness expansion sheds important light on the historical underpinning of its contemporary development model.

In most development thinking, agriculture has taken a backseat to industry: with industrialization seen as synonymous with development, agricultural modernization has been viewed primarily as a foundation for industrial growth (De Janvry 2010). It is widely acknowledged that, for many successful developers, improving the productivity of agriculture has been an important part of their industrialization process and the state has played a central role in propelling agricultural transformation. The Asian NICs, for example, pursued policies of agricultural modernization to successfully generate rapid productivity and output growth in agriculture, thereby increasing food supply, releasing labor to industry and boosting rural incomes to foster social stability and support for the national development project (Burmeister 1990; Francks, Boestel and Kim 1999; Kohli 1999; World Bank 1993). As the World Bank (1993: 32) indicates:

> East Asian governments have actively supported agricultural research and extension services to speed diffusion of Green Revolution technologies. Their substantial investments in irrigation and other rural infrastructure hastened adoption of high-yielding varieties, new crops, and the use of manufactured inputs, such as fertilizer and equipment, to cultivate them.

Importantly, though, in such countries, agriculture was harnessed to support, and subordinated to, the national industrialization project (Burmeister 1990).[2] While there has thus been recognition of the importance of state intervention in agriculture to the process of development,

[2] Scholars have also highlighted development linkages between the agricultural and industrial sectors: improvements in agriculture can promote growth of manufacturing industry through spillover effects (Burmeister 1990) and measures to boost manufacturing output can likewise contribute to productivity increases in agriculture (Wade 2010).

this has been seen primarily as a means to foster rapid growth of the manufacturing sector and its exports, rather than as a vector of export-led growth in itself.

With agriculture viewed as a backwards sector, a core premise of existing theory is that development requires moving from the production of agricultural and other commodities to manufactured goods. As Harriet Friedmann (1994: 261) states, "the ideology of development [has] focused, to the point of obsession, on industrialization." Yet, as I will show, over time, agriculture itself has become highly industrialized, capital-intensive and – particularly with recent growing global demand and food scarcity – lucrative. This has been connected to other changes in the international division of labor. It is no longer simply the case that the Global South produces and exports primary products and the Global North manufactured goods (Frobel, Heinrichs and Kreye 1981). On the contrary, even by the 1980s, the Global South had come to export more manufactured goods than primary products, and the Global North exported considerably more primary products than the Global South (Harris 1987). Between 1950 and 1980, the developing world's share of world agricultural exports dropped dramatically, from 53 to 31 percent (Grigg 1993: 251). At the same time, the US and Europe dramatically expanded their share of global production and consolidated their positions as the world's dominant agricultural exporters, through an enormous increase in their agricultural productivity fueled by technological advance and a protective trade policy regime of tariff and subsidies (Wolfe 1998). Within the new international division of labor that has emerged over the last several decades, capital-intensive production and the production of intellectual property are concentrated in the developed world, while the developing world has come to be associated with low-skilled, labor-intensive production, whether in traditional agriculture or manufacturing.

As I demonstrate, the dominant form of agriculture that has now emerged in Brazil (as well as other major exporters like the US, Europe, Canada and Australia) is *industrialized agriculture*, capital-intensive and technologically-sophisticated. It is "high-tech" agriculture, employing advanced machinery and production methods, engineered seeds and chemicals, and large economies of scale. The expansion of Brazilian agribusiness has involved a substantial increase in capital stock (Rada and Valdes 2012). In fact, agriculture is now the most capital intensive sector in the Brazilian economy – more so than either manufacturing or services – and Brazilian agriculture is relatively more capital-intensive than any other country, including the US (Spolador and Roe 2013). Consequently, it could be argued that industrialized agriculture in Brazil has more in common with industrial manufacturing than traditional peasant or plantation agriculture, and in this respect conforms to the expectations of neostatism about the underlying source of development being capital-formation.

Moreover, in the contemporary global economy, the new marker of development is no longer the presence of manufacturing industry but what Alice Amsden (2001) calls "knowledge-based assets" – research and development-fueled knowledge, technology, and intellectual property. Ha-Joon Chang likewise argues that it is their "technological capabilities" – the differential ability to develop and use technologies – that distinguish developed from developing countries (Lin and Chang 2009: 490). It is precisely such knowledge-based assets that have been the basis of Brazil's agriculture boom, which has been technology-driven and, importantly, based on domestic innovation. While in an earlier period of dependent development, Brazil's industrial development (like that of other semi-peripheral countries) was heavily dependent on foreign technology (Evans 1979), its recent emergence as an agro-power has been driven by indigenous

technological development. Indeed, Brazil is now even exporting its advanced agricultural technology and know-how to other countries.

Importantly, Brazil has used technological innovation specifically to construct a new comparative advantage in *temperate* agricultural products. Previously, the production of temperate commodities was heavily concentrated in rich countries and tropical commodities in poor countries. Tropical climates are unfavorable for intensive cultivation of staple crops and livestock (Gallup and Sachs 2000), and the world's top agricultural exporters were therefore rich countries – twenty years ago, the world's top 10 food exporters did not include a single developing country (World Bank 2013: 2). Furthermore, global market conditions have differed significantly for temperate versus tropical products: tropical agricultural products have experienced stronger and steeper long-term deterioration of prices than temperate agricultural products, as well as greater volatility (Erten and Ocampo 2013; Jomo and von Arnim 2012; Lewis 1969). This distinction is shaped by labor market dynamics, with the excess supply of labor in tropical agriculture exerting downward pressure on prices for tropical products, and the fact that "countries that produce tropical goods compete with other poor countries at the international level in markets involving very little value-added" (Bértola and Ocampo 2012: 88). Growth in the tropical agricultural products typically exported by developing countries – such as coffee, cocoa and tea – has also been held back by sluggish and saturated demand in developed markets (FAO 2002: 25). In contrast, Brazil has successfully moved into the production of temperate products, incorporating greater value-added and benefiting from more buoyant demand conditions (Poulton 2008). Key areas of Brazil's agriculture expansion – such as meat and animal feed – have experienced rapidly and continuously expanding demand propelled by growing incomes and protein consumption across the developing world. Meat, for instance, is a

high-value product because it is relatively capital-intensive and expensive to produce (Elliott 2006) and livestock production relies heavily on the availability of large quantities of low-cost feed grains, such as soy and corn – which, until Brazil's agriculture transformation, were temperate products. Defying the constraints of its climate, Brazil has thus used state-led innovation to become the first tropical country to join the ranks of the world's leading agricultural producers, while also using its enhanced productivity in bulk commodity production to fuel the expansion of higher-value, downstream agro-processing industries (such as feed/meat and sugarcane/ethanol) (Poulton 2008).

**Background: A Brief History of Agriculture in the Brazilian Economy & Policy**

Like many developing countries, the export of agricultural commodities has long played a role in Brazil's economic history, dating back to the colonial era. Into the early decades of the twentieth century, the Brazilian economy centered on the export of coffee and other commodities such as rubber to markets in Europe and the US. It was a situation of classic dependency, with Brazil reliant on the export of cheap primary products and the import of more expensive manufactured goods (Cardoso 1972). Concerned about its dependence on primary product exports in the context of declining terms of trade, Brazil embarked upon import-substitution industrialization beginning in the 1930s and accelerating in the 1950s-70s (Evans 1979). Economic policy during this period emphasized the subordination of agriculture to industrial development. Due to the success of its ISI policies, over much of the twentieth century, the importance of agriculture in the national economy declined as that of manufacturing increased and Brazil was transformed from an agrarian to a major industrial economy (Weyland 1998). Brazilian agriculture consisted primarily of large plantations producing tropical products for export, small family farms supplying the domestic market, and peasants engaged in subsistence

production. As recently as the 1970s, Brazil was a net-agricultural importer and, until the 1960s, it systematically received food donations from abroad (Martha, Contini and Alves 2013).

The international debt crisis of the early 1980s plunged Brazil into an economic crisis, faced with major balance of payments problems, soaring inflation, and an inability to meet its international debt obligations. Policymakers determined that the old model of an inward-looking economy with substantial state intervention to promote industrial development was no longer sustainable. Over the 1980s and 1990s, Brazil introduced a major program of economic reform and liberalization, involving aggressive inflation fighting to stabilize the macroeconomic environment, the elimination of foreign trade restrictions and barriers to foreign investment, and reducing state intervention in markets. In agriculture, reforms included privatizing state enterprises, reducing subsidies, and eliminating government purchases, marketing boards and minimum support prices. As I will show, liberalization had an explosive effect on the growth of Brazil's agribusiness sector and its exports. But this was not simply a story of the triumph of neoliberal economic reforms, unleashing the market and prompting a flourishing of private enterprise. On the contrary, the foundation for Brazil's transformation into an export powerhouse was laid a decade earlier in the 1970s, with a set of state policies that played a crucial role in constructing Brazil's new comparative advantage in agriculture.

**The Making of an Agro-Export Powerhouse**

Brazil's emergence as an agro-power has its origins in policies and investments put in place by the state at the height of its ISI program during the 1970s. At that time, the primary goal of the Brazilian state was boosting the country's position in the international division of labor by fostering the development of its manufacturing industries. Paradoxically, the transformation of Brazilian agriculture was instigated by its industrialization drive. The

Brazilian state launched an ambitious effort to modernize Brazil's stagnant agricultural sector and increase production, in the service of its industrialization project. Crucially, enhancing the agriculture sector was seen as a means to an end – continued industrial development – not an end in itself. The state had two primary goals. One, rapid urbanization associated with industrialization had created a food supply crisis, manifest in high prices for basic foodstuffs (creating demands for higher wages from urban workers), long lines in supermarkets, and social unrest (Alves 2010). The food supply shortage threatened to derail industrialization. Seeking to maintain social stability and the country's high growth rates, the military government was eager to increase the supply of food and alleviate upwards pressure on domestic prices. Two, the state also sought to diversify and expand agricultural exports in order to generate foreign exchange to finance imports of technology and capital goods necessary to continue the process of industrialization (Contini and Martha 2010). This was particularly attractive due to high global agricultural prices at the time. The state-led initiatives that ultimately spurred the transformation of Brazil's agriculture sector were thus undertaken with the objective of increasing agriculture production as a means to fuel its ISI project, by providing cheap food for the domestic market and foreign exchange revenues from export earnings. State policies did indeed wind up altering the nature of Brazil's role in the global economy, but the direction of the economic transformation the state initiated was exactly the reverse of the one it intended: a set of policies launched to support the country's industrial development eventually helped to transform it into one of the world's dominant agricultural powers. Agriculture, which was given a supporting role during Brazil's import substitution industrialization, ultimately came to steal the show.

The effort to modernize Brazilian agriculture centered on research and development, backed by subsidized credit and agricultural extension services to facilitate the diffusion of new

technologies. At the hub of this strategic initiative was the creation of a new federal research institute, the Brazilian Enterprise for Agricultural Research (EMBRAPA), in 1973. EMBRAPA was charged with constructing a large research infrastructure of laboratory and other facilities, supported by substantial investments in research and development and advanced scientific training and capacity building (Contini and Martha 2010). By the late 1970s, EMBRAPA had nearly 1000 researchers, including agronomists and veterinary personnel specializing in plant production, genetic improvement, soil science and phytopathology, and biotechnology (Wilkinson and Sorj 1992). In addition to conducting its own direct R&D, EMBRAPA coordinated nationwide agricultural research through the Brazilian Agricultural Research System, encompassing state agricultural research organizations, universities and its own research operations (Martha, Contini and Alves 2013).

It was the stream of scientific and technological innovations eventually produced by EMBRAPA that propelled the development of Brazil's contemporary agro-industrial export sector. Initially, EMBRAPA's work centered on adapting technologies developed elsewhere – primarily in the US, the world's leading source of agricultural innovation – to conditions in Brazil's existing agricultural zones (Wilkinson and Sorj 1992). Overtime, however, EMBRAPA increasingly shifted its focus towards domestic innovation, which is what catalyzed Brazil's agricultural expansion. Its research was directed towards increasing productivity and adapting agricultural systems to the distinctive ecosystems of Brazil's agricultural frontier: the Amazon, the Pantanal, the semi-arid interior, and especially the *cerrado* (Wilkinson and Sorj 1992). Substantial investments were made in the development of novel, science-based technologies for tropical environments, including plant genetics and new seed varieties, soil correction and

management, and improved agricultural practices adapted to the use of industrial inputs and machinery (Martha, Contini and Alves 2013).

*Nature versus Nurture: The Role of State-Led Innovation*

Brazil faced two significant barriers to expanding its agriculture sector: a lack of land suitable for agriculture (either for growing crops or grazing animals) and an unfavorable climate. This assertion may seem surprising. Brazil is, of course, favored with the world's fifth largest endowment of land, as well as an abundant supply of water. Of the three factors of production – land, labor and capital – Brazil clearly started out with an abundance of the one – land – that would be expected to offer a comparative advantage in agriculture. Yet, in fact, much of its land was unfit for commercial agriculture.

In the late 1960s, more than half of the national territory remained untouched by agriculture (Martha, Contini and Alves 2013). In particular, the vast *cerrado* region – a savannah that stretches for more than 1,000 miles across central Brazil and accounts for 24 percent of the country's total area – was considered unsuitable for agriculture due to its acidic and infertile soil. Its Portuguese name denotes "closed, inaccessible land" and, indeed, the *cerrado* was "written off as useless for centuries" (Rohter 2007). As Martha et al (2013: 207) state, "the stock of agricultural technologies and empirical knowledge at that time indicated that the agricultural frontier – the 'Brazilian Cerrado' – could, at best, accommodate only subsistence farming." In the words of Norman Borlaug, the Nobel Peace Prize-winning agronomist considered the originator of the Green Revolution, "nobody thought these soils were ever going to be productive" (cited in Rohter 2007).

Brazil also faced a second, and equally significant, obstacle. Most of its landmass is in a tropical climate, but tropical climates generally provide acidic, weathered soils of low fertility

that cannot sustain the bulk crops grown in temperate climates (Gallup and Sachs 2000). For this reason, it had long been an accepted fact that only temperate regions could effectively and efficiently engage in large-scale, intensive agricultural production.

Crucially, however, technological innovation driven by state-sponsored R&D and related policies enabled Brazil to overcome both of these seemingly insurmountable hurdles. New technologies developed by EMBRAPA transformed Brazilian agriculture by turning the *cerrado* into arable and pasturable land and thereby enabling the expansion of commercial agricultural production. In less than a generation, what was once considered a wasteland was transformed into one of the most important productive regions of the country, and indeed the world (Horton and Borges-Andrade 1999). Simultaneously, state-directed research carried out by EMBRAPA led to the development of new seed varieties and accompanying agricultural practices tailored to tropical conditions, thus making possible the emergence of a highly sophisticated and competitive agriculture sector in Brazil. This state-led technological innovation enabled Brazil to move away from the tropical products typically exported by developing countries (coffee, tea, sugar, bananas, etc.) to producing and exporting commodities (soybeans, cotton, beef, chicken, pork, etc.) that directly compete with the world's dominant agricultural producers – the US, EU, and other countries of the Global North.

*From Wasteland to Agricultural Heartland*

The technological innovations developed by EMBRAPA led to a transformation of revolutionary proportions in Brazilian agriculture. It was state-led innovation produced by EMBRAPA that enabled both cropland and grazing expansion into the *cerrado*. New technologies developed by EMBRAPA made it possible to improve soil chemistry and thereby turn it into arable land (Rada and Valdes 2012). The *cerrado's* tropical soils are naturally highly

acidic, low in fertility (due to a lack of important nutrients such as nitrogen, phosphorus, and potassium), and prone to degradation (Huerta and Martin 2002). In short, left on its own, the soil of the *cerrado* is effectively toxic to agriculture. To reduce the soil's toxicity, EMBRAPA deployed a technique called *agricultural liming,* applying massive quantities of lime to the soil to lower acidity and neutralize its pH levels, along with phosphorus to improve fertility (Correa and Schmidt 2014). EMBRAPA also developed new varieties of *rhizobium*, a bacterium that helps fix nitrogen in legumes (such as soy), specifically for the *cerrado* soil, in order to reduce the need for fertilizers (Correa and Schmidt 2014).

EMBRAPA also developed and promoted other important technical solutions to address soil conditions in the *cerrado,* including soil recuperation, "no-till" agriculture, and integrated systems of crop production and cattle grazing (Correa and Schmidt 2014). Due to its fragile soils, for example, the *cerrado* is highly vulnerable to erosion. EMBRAPA pioneered a system of no-till production: rather than ploughing the soil or harvesting the crop at ground level, it is cut high on the stalk and the remains of the plant are left to decompose into a fertile covering of organic material, into which the next crop is planted directly, thereby retaining more nutrients in the soil (Huerta and Martin 2002). In 1990, Brazilian farmers used no-till farming for 2.6 percent of their grains; today that figure is over 50 percent (*The Economist* 2010).

At the same time, through its plant breeding programs, EMBRAPA developed more productive grass varieties that provided a significant technological breakthrough in creating pastureland in the *cerrado* (Rada and Valdes 2012). Its scientists, for example, successfully adapted the *brachiaria* species native to savannahs in Africa, which has a high nutritional value, provides greater nitrogen fixation and requires less phosphorus fertilization than native pastures. They created a variety in Brazil, called *braquiarinha*, which produces 20-25 tonnes of grass feed

per hectare, many times what the native *cerrado* grasses produce and three times the yield of the original variety in Africa. This meant that parts of the *cerrado* could be turned into highly-productive pasture, fueling a massive expansion of Brazil's beef industry and a dramatic increase in its productivity. The time it took to raise cattle for slaughter Brazil dropped from 4 to 1.5 years (Correa and Schmidt 2014). As a result, Brazil's beef production increased nearly 4 fold and it has become the world's largest beef exporter, supplying 30 percent of the global market (Contini and Martha 2010).

The transformation of the *cerrado* has been described as "one of the greatest achievements of agricultural science in the 20th century" (Rohter 2007). The *cerrado* now accounts for 70 percent of Brazil's farm output and is one of the top grain and beef-producing regions in the world (Pereira and Neves 2011; Reed 2014). The expansion of Brazilian agriculture into the *cerrado* had important implications not only for the levels of Brazilian production but also its competitiveness. Brazil's commercial agriculture, particularly grain crops, had previously been concentrated in a relatively small temperate region in the South, where supply constraints contributed to high land prices. Due to the new technologies developed by EMBRAPA, producers from that region were able to expand their operations into the *cerrado*. Moreover, since the enormous quantity of land it offered had previously been largely idle, it was available cheaply and thus significantly improved the international competitiveness of Brazilian producers (Correa and Schmidt 2014).

*Producing Temperate Crops in a Tropical Climate*

The impact of EMBRAPA's plant breeding programs in adapting temperate crops to Brazil's tropical climate has been equally momentous. This has been most striking in the case of soybeans, which has become the *cerrado's* main crop (Goldsmith and Hirsch 2006). Soybeans

are naturally suited to grow in latitudes above 30 degrees, are sensitive to temperature changes and require four distinct seasons, and had therefore always been considered a crop only possible to grow in temperate climate zones. All other major soybean producers (such as the US and Argentina) have temperate climates, and Brazil itself grew some soy in its temperate Southern states. Through cross-breeding and genetic improvements, however, EMBRAPA created new soy cultivars that could grow in tropical climates, with greater tolerance for soil acidity, thereby enabling the expansion of soybean production out of the traditional Southern states into the *cerrado*, as well as the arid northeast (Wilkinson and Sorj 1992).

EMBRAPA also developed new soybean varieties that grow more quickly, with a life cycle as much as 12 weeks shorter than normal. This faster growing period has enabled Brazil to operate two full harvests per year, significantly increasing yields and the land productivity of Brazil's soy industry, while providing a marked advantage over traditional producers like the US, who are limited to only one annual harvest (Huerta and Martin 2002). EMBRAPA has developed more than 40 tropical varieties of soybeans, including cultivars with greater resistance to pests and diseases, reducing crop losses as well as expenditures on insecticides and contributing to higher yields (Correa and Schmidt 2014; Rohter 2007). Inoculating soybean seeds with nitrogen-fixing bacteria, described above, has almost eliminated the need for nitrogen fertilizers, leading to savings estimated at R$7.5 billion per year (Correa and Schmidt 2014). Propelled by these innovations, Brazil now poses a significant competitive challenge to the US, which historically dominated world soy markets and accounted for more than 75 percent of global exports (Gibson and Benson 2005). Brazil has become the world's second largest soy exporter, claiming 39 percent of the global market.

EMBRAPA has made similarly important technological advances in other crops. Brazil's cotton sector, for example, had long suffered from low productivity, plant disease, and fierce international competition. That was until EMBPRAPA developed new varieties of cotton adapted to tropical conditions, which made it possible to achieve considerably higher yields – tripling between 1983 and 2010 – and fiber quality (Correa and Schmidt 2014). Brazil has since become a rapidly-rising cotton producer and is now the world's fourth largest exporter. In addition, beyond soy and cotton, EMBRAPA has also produced new cultivars for a wide range of other species, including rice, wheat, oats, beans and forage (Wilkinson and Castelli 2000).

*The Contributions of State Policies*

Through these innovations, state-sponsored research and development has played a fundamental role in expanding Brazil's agricultural frontier and boosting levels of productivity (Wilkinson and Sorj 1992). Between 1970 and 2010, Brazilian agricultural production more than tripled, and it is projected to increase a further 38 percent from 2010 to 2019 (Contini and Martha 2010; OECD/FAO 2010). Productivity gains accounted for approximately 70 percent of this growth in output and land area expansion the remainder (Barros 2009). As Contini and Martha (2010: 3) state, "the sector moved fast forward from a traditional to a science-based agriculture." State-led innovation contributed centrally both to this increase in productivity and to the territorial expansion of agriculture, which, combined, simultaneously lowered the overall costs and increased the yields of Brazilian agriculture (Rada and Valdes 2012).

These technological advances have also been supported by other important policy measures. First, EMBRAPA has provided extension services to facilitate rapid diffusion of its research discoveries and the adoption of the novel production systems it has developed by Brazilian farmers (Rada and Valdes 2012). Second, the adoption of new technology packages

and the expansion of agricultural production into previously idle regions was further stimulated by a national system of subsidized credit (Wilkinson and Sorj 1992). Loans were provided at artificially low interest rates, with an extended grace period and low payments that allowed producers to keep and reinvest a sizeable portion of their profits. State-sponsored credit peaked in the 1970s, during Brazil's ISI period, with high rates of rural credit provided by the state at heavily subsidized interest rates; yet, although rural credit was reduced substantially with structural adjustment in the 1980s and early 1990s, it has risen steadily since then (Contini and Martha 2010). Access to cheap credit played an important role in helping producers gain access to and apply the new productive systems that were being developed by EMBRAPA. It also enabled large producers from the Southern states (Rio Grande do Sul, Parana and São Paulo) that had constituted the traditional center of commercial agriculture in Brazil to expand their operations into the *cerrado*.

Brazil's agricultural revolution has thus been fueled by large and sustained public investments in science and technology and associated policies (Rada and Valdes 2012). It was only through extensive state support – for R&D, as well as extension services and subsidized financing – that incorporating the *cerrado* into Brazilian agricultural production, and using that land to grow temperate crops, was possible. Through state-led innovation, Brazil dramatically increased its effective agricultural land supply, along with the productivity and global competitiveness of its agribusiness sector.

*Brazil's Resulting Agro-Export Boom*

State intervention originating in the ISI period thus set the stage for the take-off of Brazil's agribusiness sector with economic reform and market opening in the 1990s. The combination of technological innovation and economic liberalization led to explosive growth in

Brazilian agricultural production and exports (Wilkinson 2009). Liberalization generated substantial investment, restructuring and consolidation in the sector, spurring rapid and sustained export-led growth. In just a four year period, from 2000-2004, total planted area grew by an area larger than the size of Italy or Vietnam (ICONE 2006). Exports have grown at astounding rates as high as 20 percent per year (Valdes 2006). This growth has been driven by the expansion of corporate farming, including the emergence of "mega farms" – large, professionally managed corporate farm groups benefitting from massive economies of scale, many with planted areas in excess of 1 million hectares. The agro-industrial sector that has developed in Brazil is among the world's most sophisticated, based on large-scale, mechanized, capital-intensive, vertically-integrated production (Valdes 2006).

Brazil has emerged as an agro-industrial powerhouse: it is one of the most competitive agricultural producers in the world and a leading exporter of a large and growing number of products (Table 1). Brazil is now the third largest agricultural exporter, after the US and EU, and the country with the largest agricultural trade surplus.[3] It is the first country to catch up with the traditional "big five" grain exporters (the US, Canada, Australia, Argentina, and the EU). Moreover, its exports are expected to continue to expand rapidly over the next decade and beyond, and Brazilian producers and officials believe that it could well surpass the US as the world's leading agricultural exporter.[4] Brazil has undoubtedly arrived among the world's "agro-powers" (Margulis 2014). Importantly, it is the only tropical country to achieve the status of an agricultural superpower; all others have temperate climates.

**Table 1: Brazil – Selected Agricultural Exports, 2009**

| | World Rank | Market Share of Global Exports (%) | Projected Growth in Next Decade (%) |
|---|---|---|---|

[3] FAO Data 2011.
[4] Interviews with Brazilian agribusiness representatives and government officials, Brasilia and Sao Paulo, May 2010.

| | | | |
|---|---|---|---|
| Beef | 1 | 30 | 46 |
| Poultry | 1 | 39 | 52 |
| Sugar | 1 | 45 | 40 |
| Ethanol | 1 | 52 | 155 |
| Orange Juice | 1 | 86 | 27 |
| Coffee | 1 | 32 | * |
| Soybeans | 2 | 39 | 33 |
| Corn | 3 | 10 | 65 |
| Pork | 4 | 12 | 32 |
| Cotton | 4 | 6 | 77 |

Sources: AGE/Ministério da Agricultura, Pesca e Abastecimento, USDA.
* No projections available.

Brazil's highly-industrialized, export-oriented agriculture sector now plays a major role in its economy. Agribusiness has become a core engine of economic growth, contributing 28 percent of GDP and over 40 percent of exports (Damico and Nassar 2007; Valdes 2006). Agriculture exports make a substantial and essential contribution to Brazil's trade balance, providing a critical means of generating foreign exchange and avoiding the balance-of-payments problems that have historically plagued the country. Agro-exports helped to fuel nearly a decade and a half of trade surpluses that enabled the accumulation of $350 billion in foreign reserves,[5] making Brazil a net international creditor for the first time (De Onis 2008). As one Brazilian official stated, "Just look at the figures – my macro[economic] stability depends on agribusiness." [6] Brazil's economy has slowed significantly since 2010; yet, amidst growing economic and political turmoil, agribusiness has remained "an island of prosperity and economic dynamism in a national context of losses and lack of investment" (Ioris 2015: 2).

By fueling strong rates of economic growth, agribusiness contributed to a substantial increase in fiscal revenues in the 2000s, which was channeled directly into income transfers to the poor (Ban 2012; Barbosa-Filho 2008; Spolador and Roe 2013). The government raised the

[5] IMF Data.
[6] Interview, Geneva, May 2009.

minimum wage and expanded social welfare policies through programs such as the *Bolsa Familia*, an income transfer to poor households, and Zero Hunger, a program to combat food insecurity and extreme poverty. These policies have succeeded in reducing poverty, especially extreme poverty, as well as inequality (Soares, Ribas and Osorio 2007). The poverty rate has fallen from 30 percent in 1990 to 11 percent in 2009 – lifting over 24 million people out of poverty – while inequality has fallen from a GINI of 60 in 2001 to 55 in 2009.[7] As Antonio Ioris (Forthcoming) details, the activity of the contemporary Brazilian state depends on agriculture to help manage a substantial public debt and sustain welfare-related programs.

Brazil's agribusiness boom has fueled a dramatic expansion of Brazilian firms. There are now approximately 20 Brazilian agribusiness companies with annual sales of more than US$1bn and others poised to soon reach this level (Hopewell 2014). Brazilian firms have diversified their activities and moved up the value chain into higher value-added activities, including trading, processing, transport, and energy (biofuels). Many of Brazil's largest companies have globalized their activities and joined the ranks of the world's leading agribusiness multinationals, in part through aggressive campaigns of foreign investment and acquisitions. JBS, for instance, has become the world's largest meatpacker, with annual revenues of over US$40bn. JBS acquired many of the largest beef, pork and chicken processing companies in the US and Europe and now operates 150 plants around the world, with 190,000 employees and exports to 110 countries.[8] BRF-Brasil Foods has emerged as one of the world's largest processed food producers, operating in 110 countries, with $14bn in annual revenues and 130,000 employees.[9] The major Brazilian firms have transformed themselves into global actors, targeting foreign

[7] World Bank Data.
[8] Company data.
[9] Company data.

markets and engaged in extensive production and trading activities around the world. Here too, the hand of the Brazilian state is evident, playing a critical role in financing the expansion and internationalization of Brazilian agribusiness by supplying low cost loans for investment and foreign acquisitions through the National Development Bank (BNDES) (Hochstetler and Montero 2013).

EMBRAPA remains an important force, now operating nearly forty centers and employing over 9,000 people, including a research staff of 2,000. It continues to generate a significant and wide-ranging stream of innovations, creating and transferring more than 9,000 technologies to Brazilian farmers and building a large intellectual property portfolio. EMBRAPA also began internationalizing its activities in 1998, providing technical training and capacity-building to other developing countries and disseminating its technologies and expertise, with a focus on biofuels and tropical agriculture. In the process, it has become a key element of Brazil's foreign aid policy and efforts to foster South-South cooperation and, consequently, an important source of soft power for Brazil (White 2010). Brazilian political leaders and officials celebrate these endeavors as helping other countries in the Global South to achieve economic growth and development through agricultural modernization and the fostering of competitive, market-oriented agro-export industries, while also improving food security and contributing to poverty-reduction. EMBRAPA currently has cooperative arrangements in place with 56 countries; it has been particularly active in Africa, where it has projects in 38 countries (Cabral and Shankland 2013). One such initiative, for example, involves transferring and adapting Brazil's successful technologies for boosting cotton yields and quality to the "Cotton-4" countries (Mali, Benin, Chad and Burkina Faso), which have been strategically important supporters of Brazil's challenge to US subsidies at the WTO (Alves 2013). Among the most

high-profile initiatives is ProSavana – a project launched in 2011 to transfer and adapt Brazilian technology and expertise to Mozambique, where soil and climate conditions are similar (Wolford 2015). The project, which is essentially an effort to replicate Brazil's model of intensive, export-oriented agriculture in Africa, has been criticized by many civil society organizations (GRAIN 2013). Despite such criticism, technical cooperation in agriculture has factored prominently in Brazil's efforts to build alliances and strengthen relations with other developing countries, as part of the country's broader ambitions to increase its status and influence on the international stage.

**Brazil as a New Development Model?**

Brazil has emerged as an agricultural export powerhouse and achieved considerable success in reducing poverty. Yet, the consequences of Brazil's path of industrialized, export-oriented agriculture are complex and far from unambiguously positive. Although the *cerrado* had previously been a wasteland from the perspective of commercial agriculture, it was neither vacant nor barren in reality. While population density was low, the *cerrado* was home to peasants and indigenous peoples and supported rich biodiversity (Machado 2009; Oliveira 2013; Pires 2000). The expansion of Brazilian agribusiness – in the *cerrado* and elsewhere throughout the country – has been accompanied by the (often violent) expulsion of peasants and indigenous peoples from the land (Sullivan 2013). Brazil's highly unequal land distribution has only been exacerbated by economic liberalization and the industrialization of agriculture. Brazil's agro-industrial model has also come with significant environmental impacts, including soil degradation, water contamination, air pollution, deforestation, and the loss of biodiversity (Rodrigues 2009). The negative environmental impacts of industrialized agriculture are particularly acute in the *cerrado*, where countering the soil's natural acidity and raising fertility requires the application of massive quantities of industrial fertilizers (Rada 2013). As a result,

there has been extensive criticism from social movements, such as the Landless Workers Movement (MST), of the social and environmental costs of Brazil's intensive commodity-export model (IBASE 2015; MST 2009).

Spurred in part by Brazil's success, after decades of relative neglect, the World Bank and other key development actors are now placing renewed emphasis on agriculture as a source of development and poverty reduction (De Janvry 2010; World Bank 2008). The Bank devoted its 2008 World Development Report to the subject of "Agriculture for Development," arguing that "it is time to place agriculture afresh at the center of the development agenda." The report focused considerable attention on Brazil, now widely held up as a model for other developing countries to emulate (Margulis 2015). The World Bank has identified underinvestment in agriculture R&D as an instance of "market failure", thereby legitimating a potential role for public investment. Alongside standard Washington Consensus prescriptions, such as liberalizing trade, strengthening property rights, facilitating efficient markets and a favorable investment climate, the Bank is now advocating investment to foster technological innovation in agriculture, with an emphasis on public-private partnerships and biotechnology. However, while the World Bank (2008: 1) states that "today's agriculture offers new opportunities to hundreds of millions of rural poor to move out of poverty," there is reason to be skeptical of such claims.

The Bank and others stress the potential for integrating small-scale agricultural producers into global markets (Akram-Lodhi 2008). But that is far from what has occurred in Brazil: the success of its agribusiness sector has been built on one of the most unequal land structures in the world, with just 1.5 percent of rural land owners effectively occupying 53 percent of all agricultural lands (Clements and Fernandes 2013). This extreme land concentration is not incidental but essential to its agro-industrial model, with the productivity and competitiveness of

Brazilian agribusiness predicated on massive economies of scale and large-scale land holdings. To replicate Brazil's model in most developing countries would require the concentration of land holdings through the mass displacements of peasants, with extreme social upheaval and potential for injustice, which many contend is occurring across diverse parts of the world in a new "global land grab" (Margulis, McKeon and Borras 2013).

It is also important to recognize that, in the Brazilian case, agricultural exports and growth alone were not sufficient for poverty reduction. Particularly since industrialized agriculture is highly capital-intensive, limiting its capacity for direct employment creation, redistributive measures were essential to achieving reductions in poverty and hunger in Brazil. Any normative appeal of Brazil's agro-export model is thus heavily contingent on concerted redistribution policies by the state. Given efforts to internationalize the Brazilian experience to sub-Saharan Africa and other parts of the developing world, this should serve as a cautionary note for proponents of schemes like ProSavana and claims that large-scale monoculture farming can lead to reductions in hunger and poverty in and of itself.

**Conclusion**

As this paper has shown, Brazil's newfound position as a dominant agricultural exporter was not a simple consequence of nature but the result of interventionist state policies that (literally) reengineered its comparative advantage in agriculture. The remarkable success of Brazil's agro-industrial sector has been based less on its natural factor endowments – which were, in fact, highly unconducive to industrialized agriculture – than on science and technology. State-driven research and development, and resulting technological advances, backed by extension services and subsidized financing, played a critical role in Brazil's emergence as an agro-export powerhouse by expanding its supply of arable and pasturable land, adapting

formerly temperate crops to the country's tropical climate and soils, and significantly increasing yields and productivity. Combined, these factors have dramatically increased Brazil's agricultural production, while reducing the costs and improving the competitiveness of its exports, transforming Brazil into a major rival to the world's leading agricultural exporters, the US and EU. What has occurred in Brazil – the construction of a new comparative advantage in industrial and formerly temperate agriculture as a result of state policies – thus defies the assumptions of both neoliberalism and developmental state theory. Far from being planned, however, Brazil's emergence as an agro-power was a largely unintended offshoot of its ambitious efforts to industrialize and foster the development of its manufacturing sector during the ISI era.

The "accidental" nature of Brazil's emergence as an agro-power raises interesting questions about the role of intentionality in development and industrial policy. The defining feature of the developmental state is typically seen as the state's capacity to direct the development process and attain its goals (e.g., Weyland 1998); in other words, intentionality – the state's pursuit of a clear and precisely delineated set of objectives – is key. Yet, the Brazilian case is not the only one to challenge this assumption. Far from following a fixed plan clearly laid out from the start, for example, China's economic development has been based on policy experimentation and a trial-and-error approach, and China's policymakers had little conception of how extraordinarily successful its reform program would ultimately become (Whyte 2009). Similarly, "pragmatic flexibility" and the use of shifting policy instruments is seen as a hallmark of the developments paths of the East Asian NICs (World Bank 1993). Contingency and fortuitous accidents have thus played an important role for other successful developers. The same also holds true for industrial upgrading in advanced economies like the US, where, for

instance, state-backed investments in technological innovation driven by military objectives have frequently produced positive spill-over effects for the development of commercial technologies (Mazzucato 2015; Weiss 2005). It is the willingness to make investments where payoffs are uncertain and the capacity to embrace the fortuitous accidents that occur that appear critical to effective industrial policy – as, for example, the Asian tigers did at times when their industrial policy followed rather than led the market (Wade 2010), or Brazil has recently done in championing its emergent agribusiness multinationals by helping to finance their internationalization. In examining actually-existing industrial policy, the notion of the state as an omniscient rational actor, capable of performing cost-benefit calculations to determine whether to enter a new industry, by weighing the costs of technological upgrading against the expected future returns, falters. As Chang argues:

> the problem is that it is very difficult to predict how long the acquisition of the necessary technological capabilities is going to take and how much 'return' it will bring in the end. … unless you actually enter the industry and develop it, it is impossible to know how long it will take for the country to acquire the necessary technological capabilities to become internationally competitive. (Lin and Chang 2009: 491)

In a world of bounded rationality and fundamental uncertainty, markets, growth and development are highly unpredictable, and the impact of innovation is inherently difficult, if not impossible, to entirely foresee. What the Brazilian case illustrates, however, is the remarkable capacity of state investments in R&D and related policies to yield unanticipated dividends.

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