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PRODUCTION AND PROTECTION:
A First Look at Key Challenges in Brazil

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CPI Report

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About CPI

Climate Policy Initiative is a team of analysts and advisors that works to improve the most important energy and land use policies around the world, with a particular focus on finance. An independent organization supported in part by a grant from the Open Society Foundations, CPI works in places that provide the most potential for policy impact including Brazil, China, Europe, India, Indonesia, and the United States.

Our work helps nations grow while addressing increasingly scarce resources and climate risk. This is a complex challenge in which policy plays a crucial role.

Foreword

Many nations are striving to simultaneously meet economic growth goals and environmental conservation goals. Efficient land use — in particular, a setting that promotes sustained growth in agricultural production alongside protection of natural resources — is at the center of achieving these goals. Increasing global demand for food and the need to address climate change risk reinforce the pressing need for efficient land use, realization of potential productivity gains, and delivery of effective ecosystem protection.

To face these challenges, many nations, including Brazil, are pursuing a joint production and protection (P&P) strategy. This report provides analytical insights to support such a strategy in Brazil. The country recently achieved important national environmental goals by enacting a new Forest Code and successfully reducing the rate of Amazon forest clearings. Brazil now seeks to move beyond deforestation to pursue sustained economic growth of its rural economy, as well as account for the environmental value of land in it. The P&P strategy offers a means to structure, assess, and implement simultaneous growth in agricultural production and protection of natural resources. It proposes an integrated approach in which land is viewed as an asset with multiple alternative, and at times concurrent, uses – forestry, agriculture, energy, mining, and peri-urban activities.

The implementation of the P&P strategy is a dynamic and interactive process. Over time, the actions of public and private actors affect land use decisions, but land use patterns and details also determine public and private action. Understanding the differences in land use across regions, and how these differences affect actors' economic decisions, can help identify potential efficiency gains. This, in turn, can contribute toward more effective policy design. In addition, integrated action across key government agencies and leading private firms helps steer the development of a P&P strategy. Effectively implementing a P&P strategy therefore hinges on the combination of regular and frequent monitoring of selected areas that represent important uses of land in Brazil with the engagement of relevant actors from both public and private sectors.

The material presented in this report should be interpreted as a starting point for consideration, rather than a comprehensive account, of the challenges that lie ahead as Brazil moves toward a P&P strategy. Some lessons are already emerging. There is ample scope for increasing agricultural production in Brazil via productivity gains. Descriptive data reveal large variation in agricultural productivity both within and across Brazilian regions. Within-region differences suggest there is room for boosting economic growth of the rural economy without compromising the protection of natural resources – growth in agricultural production can be achieved via increases in productivity, at no cost to environmental preservation. Moreover, empirical evidence indicates that agricultural productivity in Brazil systematically depends on institutional organization, technology, financing, risk management, and infrastructure. A better understanding of the nature of these associations and the underlying mechanisms driving them greatly contributes to the realization of latent land use efficiency gains.

There is also significant potential to enhance the protection of Brazil's vast stock of natural resources. As agricultural productivity gains are realized, the value of land increases, leading to rising deforestation pressures. Ensuring the strict protection of native vegetation by significantly driving up the private cost of clearing forests is thus crucial to the implementation of a P&P strategy. In recent years, Brazil has consolidated conservation efforts in public lands, but still faces large challenges in enforcing protection within private rural properties. In parallel, Brazil would benefit from the development of a sustainable forestry sector and the advancement of market-based incentives for the protection of native vegetation. The country must therefore strive to integrally incorporate the forestry sector into its rural economy. To achieve this, Brazil needs to account for and highlight the significant value of environmental preservation.

In spite of the undeniable room for action, there is only a limited amount of available information on farming and forestry in Brazil. In light of this, the implementation of a P&P strategy requires two basic preconditions. First, integrated action across government agencies and leading private firms to structure and develop the P&P strategy. Second, better characterization and understanding of how public policies and access to information, technology, and markets affect key socioeconomic decisions.

This report lays the groundwork for action on both these fronts. It is organized as follows. The next section presents an executive summary of the main findings. Chapter 1 describes the P&P concept and discusses main considerations regarding its implementation. Chapter 2 presents the overall potential for implementing a P&P strategy in Brazil. Chapters 3 through 6 then dive deeper into the sectors of forestry, large-scale cattle ranching, large-scale crop farming, and small-scale agriculture.

Enjoy reading.

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December 2013

Executive Summary

Brazil has vast natural resources that carry immense potential for the country's economic and environmental goals. As in many other nations, there is frequent tension between these goals, compounded by rising pressures from increasing global demand for food, along with climate change risk. Using land efficiently is crucial to achieve both sets of goals. Yet, the promotion of efficient land use still stands as a great challenge.

A Production and Protection (P&P) strategy is an integrated approach towards land use intended to help address these challenges. This report applies a P&P framework to Brazil to understand where land can be used more efficiently across important sectors within the country.

We find that there is ample scope for enhanced protection of natural resources and growth of agricultural production in Brazil within a P&P framework. From a protection standpoint, the country would benefit from developing mechanisms that significantly drive up the private cost of clearing native vegetation, as well as through the advancement of market-based incentives that promote sustainable practices. From a production standpoint, there is room to increase Brazilian agricultural production via productivity gains, at no apparent cost to environmental conservation.

Environmental Protection

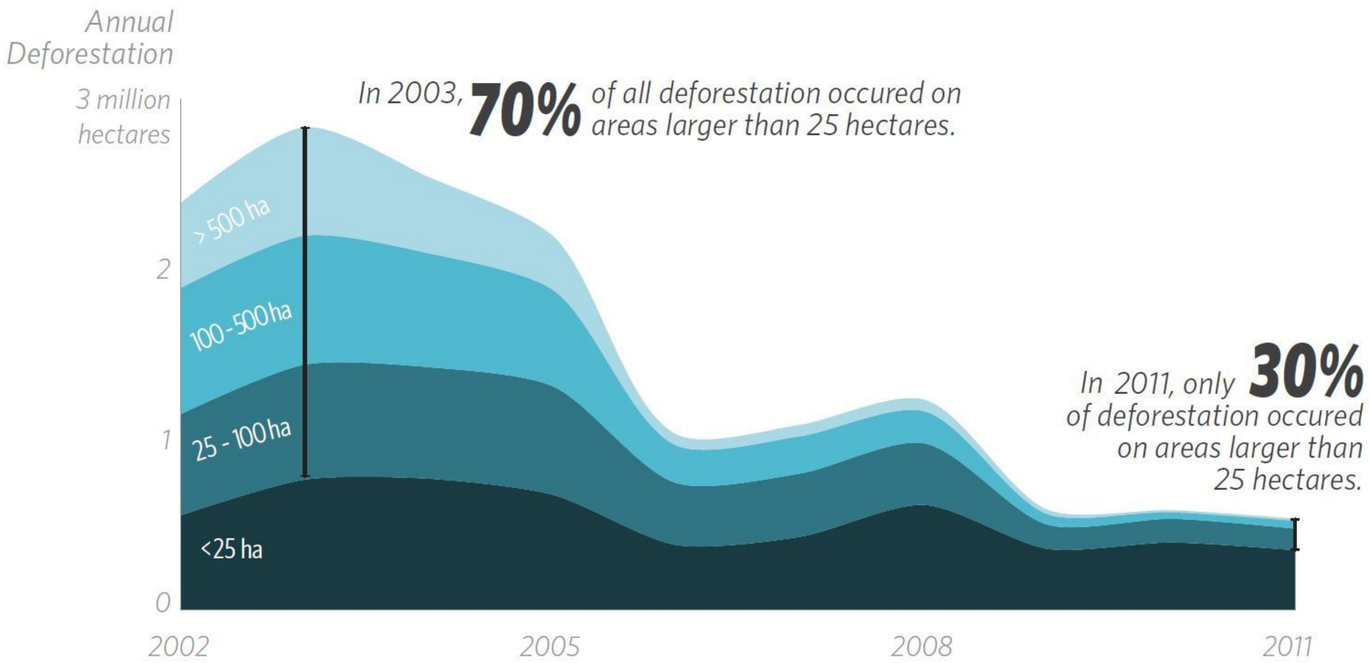
Over the past decades, Brazil has made significant progress in the protection of its natural resources. The country saw a vast expansion of protected territory – in 2006, protected areas occupied more than ten times the area they covered in 1985. Today, Brazil has a relatively consolidated institutional framework and well-established instruments for the protection of natural resources in public lands. These have been extensively used in the Amazon. However, challenges remain in the protection of native vegetation cleared in small increments, on private property, and with Brazil's ecosystems beyond the Amazon, while sustainable forestry is underdeveloped.

Ways forward to address these challenges include:

- **Improve existing monitoring techniques to adequately deal with small-scale Amazon deforestation.** Once driven by large-scale forest clearings, Amazon deforestation currently results primarily from the cutting down of forest in small increments (see Figure 1). This is likely a symptom of some of the technical shortcomings of Brazil's current system for monitoring Amazon deforestation – the system can only track forest clearing activity above a certain level. Did those who clear forests in large increments adapt their behavior to the system's known limitations, or did the profile of deforesters actually change? Answering this question requires further analysis.

- **Use the Rural Environmental Registry to effectively implement the Forest Code on private property.** Forests occupy about a third of the area of rural private landholdings in Brazil, totaling 100 million hectares of native vegetation within private properties. The new Brazilian Forest Code establishes the regulatory framework for environmental conservation in private lands, and the Rural Environmental Registry provides the key instrument for enforcing this framework. Although both framework and instrument are in place, effectively using the Rural Environmental Registry to implement the Forest Code remains a challenge. Enhanced understanding about rural property rights and compliance with environmental regulation within private properties in Brazil can provide critical insight into how to best enforce environmental regulation at the private property level.

Figure 1 Annual Amazon Deforestation Increments Grouped by Size of Forest Clearings, 2002–2011



The graph shows the participation in annual Amazon biome deforestation by forest clearing size category. Source: PRODES/INPE (2013).

- **Create mechanisms to deter deforestation outside the Amazon Forest.** To do this, Brazil needs to extend effective monitoring and law enforcement over its other five biomes, which also hold unique biodiversity and serve as carbon stocks. This applies particularly to the Cerrado biome, given that it is highly attractive to agricultural producers, and has already experienced a large extent of cleared native vegetation. A substantial share of clearings happening in this biome is legal in light of the Forest Code's regulations. Monitoring and law enforcement are therefore unlikely to single-handedly deter large amounts of deforestation in the Cerrado, reinforcing the need for incentive-based policies, such as payment for environmental services, to combat the clearing of native vegetation.

- **Develop a sustainable forestry sector and advance market-based incentives for the protection of natural resources.** Efforts aimed at promoting such actions in the country are still at very early stages. In particular, the role public policy plays in these efforts is mostly unknown.

Agricultural Production

Brazil currently stands before a significant opportunity to increase its agricultural productivity. **There is substantial variation in agricultural productivity both across and within Brazil's five regions** (see Box 1). Geographical factors explain slightly over a third of the total variation in Brazilian agricultural productivity. Non-geographical factors including access to finance, technology, rental markets, cooperatives, and infrastructure account for a substantial part of the remaining variation. We make recommendations for how to realize productivity gains through improvements in each of the non-geographical factors in turn.

Opportunities to Improve Agricultural Productivity

Access to finance

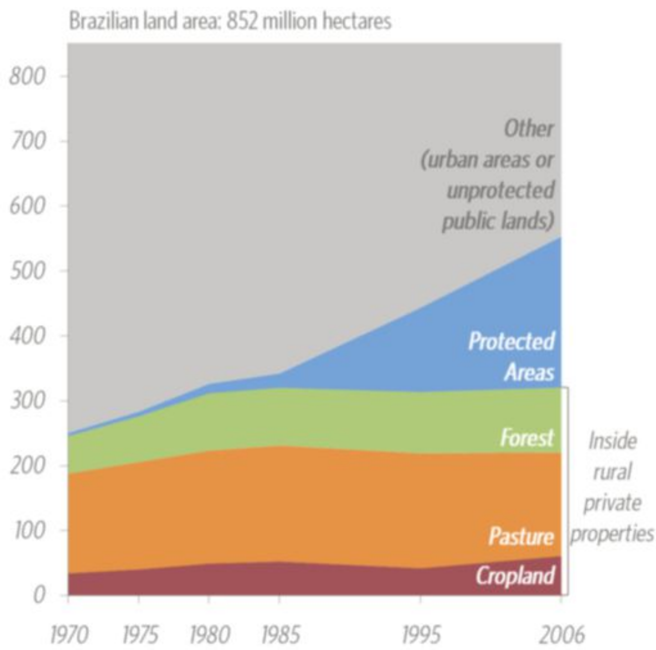
In-depth analysis is needed to better understand the impact of the provision of rural credit, Brazil's most important agricultural policy, as well as that of other financial instruments. In 2013, over BRL 130 billion was set aside as rural credit, a large share of which was loaned under subsidized interest rates. Still, little is known about rural credit's effects on production,

Box 1 – Regional variations in productivity across Brazil's agricultural sectors

The 2006 Brazilian Agricultural Census, the latest available data set on countrywide agricultural production, reveals important characteristics of Brazil's three main agricultural sectors – large-scale cattle ranching, large-scale crop farming, and small-scale agriculture.

Cattle ranching is Brazil's most land-intensive agricultural activity. In 2006, pasture occupied half the area of private rural landholdings (see Figure 2). The South, Southeast, and North regions account for less than half of the cattle ranching area in Brazil, but have higher average cattle farm productivities (see Figure 3). The Center-West region, which covers nearly 20% of Brazilian territory and contains over 35% of the country's pastureland, portrays lower cattle farm productivity.

Figure 2: Land Use in Brazil, 1970–2006



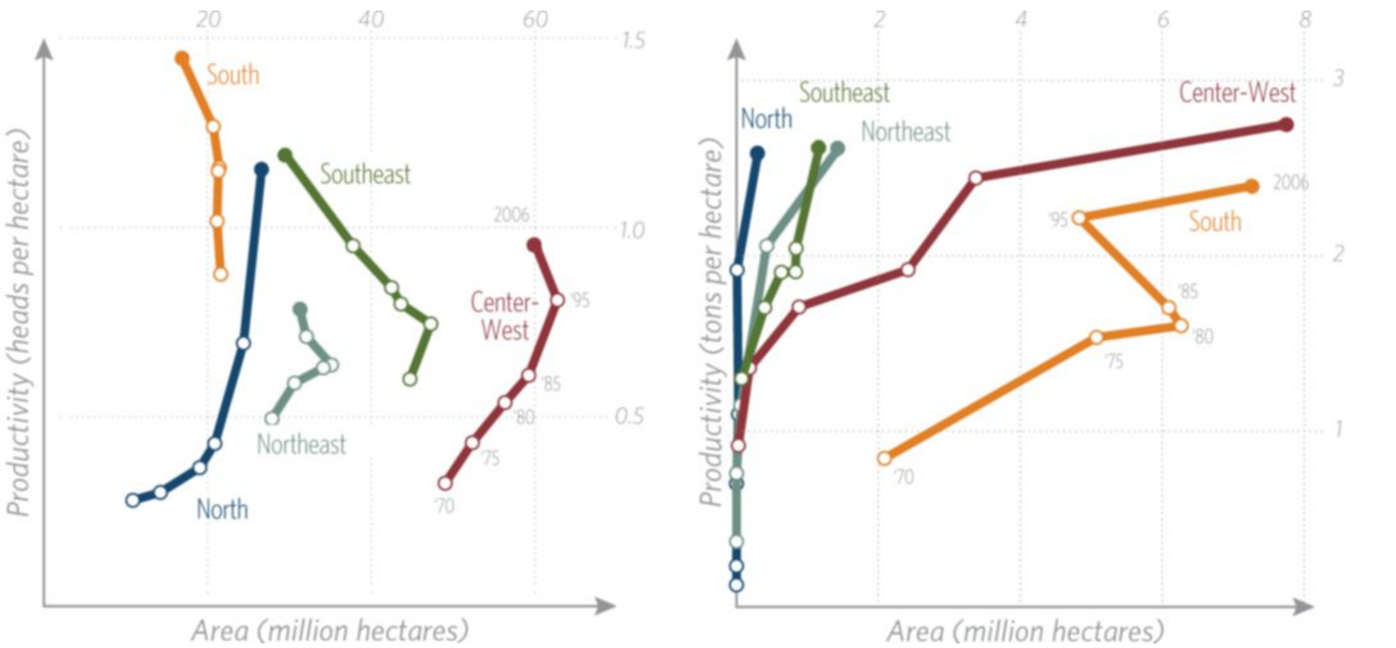
In turn, **crop farming occupies about one quarter of the non-forest area within rural private properties** (see Figure 2). Soybean, sugarcane, and maize account for approximately 60% of Brazil's cropland. Soybean is largely concentrated in the South and Center-West, and sugarcane in the Southeast, while maize is more widely distributed across regions. In 2006, crop farm productivity for soybean was similar across regions (see Figure 3), but both sugarcane and maize exhibited regional variation in productivity.

Small-scale agriculture occupies only about 25% of Brazil's agricultural lands, but accounts for 75% of the rural labor force and over 80% of rural landholdings. Increasing productivity in small-scale agriculture can thus improve the economic situation of a large share of Brazil's rural population. The distribution of land use in small-scale agriculture across cropland and pastureland is similar to that of large-scale agriculture. Yet, while large-scale crop farms are concentrated in soybean production, there is greater diversification across crops cultivated in small farms. Small-scale cattle ranching exhibits higher farm productivity in the South, while small-scale crop farming has higher farm productivity in the South and Southeast.

Land use in Brazil has become more efficient over time both across and within agricultural sectors. Indeed, average national crop farm productivity quadrupled and average national cattle farm productivity doubled between 1970 and 2006. Additionally, evidence suggests that there has been significant conversion of low-productivity pastureland into higher-productivity cropland. The share of cropland within private properties increased 37% in 40 years (see Figure 2). The Southeast region has seen a strong conversion of pastureland to sugarcane cropland since 1975. A similar trend has more recently started to occur in Brazil's Center-West – after a significant expansion from 1970 through the mid-1990s, total pastureland area in the Center-West started to decrease in 1996, as soybean cropland moved into areas once occupied by pasture. Moreover, average soybean farm productivity increased substantially since 1970 across Brazilian regions (see Figure 3).

Figure 3 Evolution of Productivity and Area for Cattle and Soybean, 1970–2006

(a) Cattle **(b) Soybean**



The graph shows the evolution of productivity and area for cattle ranching (left) and soybean farming (right) in each Brazilian region in 1970, 1975, 1980, 1985, 1995, and 2006. Source: IBGE, Brazilian Agricultural Census 2006

producers' livelihoods, and welfare in Brazil. Moreover, there is insufficient information on how policies interact with other available financial instruments, as well as on how well targeted the country's rural credit policies actually are.

Agricultural production is characterized by relatively long productive cycles brought about by the maturing of livestock, or by necessary intervals between planting and harvesting. These long productive cycles, combined with high exposure to weather and price risks render access to financial instruments crucial to enable rural producers to smooth out shocks. Credit and risk management are therefore the dimensions of financing that are most relevant to agricultural production. A variety of local arrangements are typically present in rural economies to allow producers to meet their financing needs. These arrangements include, but are not limited to, rural credit, agricultural traders, credit cooperatives, credit from suppliers, buffer stocks, and social networks.

Two key issues for improving financing for Brazil's agricultural sectors are:

- **Improve access to rural credit.** It is clear that credit significantly affects agricultural production decisions in Brazil – about 20% of the regional variation in Brazilian agricultural productivity is associated with credit availability, suggesting that greater access to credit could improve productivity. In 2006, nearly 75% of large-scale crop farmers and less than 20% of small-scale agricultural producers accessed credit. Poor access to risk management instruments imposes even greater limitations for small-scale producers – over 40% of small producers who report needing credit but not having access to it cite fear of indebtedness as one of the reasons for not seeking credit.

- **Improve information about the mechanisms through which credit policy, financial instruments, and local arrangements operate to help farmers smooth out shocks, as well as about how they interact with one another.** Little is known about how credit affects production decisions, how it interacts with the many existing local arrangements, and how this interaction influences producers as they attempt to smooth out production shocks. Additionally, knowledge about the role of other financial instruments used in the Brazilian agricultural sector is currently limited. These instruments account for over 25% of large-scale Brazilian crop farmers' external financing needs – this share is much larger in some regions, such as the Center-West, where it adds up to nearly half.

The spread of technology

Today, there is only a limited understanding about the leading channels for technological diffusion and the most relevant barriers to the spread of new technologies in Brazil. Improving this understanding can contribute to the design of policies capable of pushing producers closer to the agricultural production frontier, and even expanding the frontier itself.

The spread of new agricultural technologies contributes to productivity gains. Our analysis indicates that some of the main productivity-boosting practices in Brazil are rotational grazing and application of lime to pasture in cattle ranching, and use of direct planting systems and improved seeds in crop farming.

Three opportunities for technological diffusion currently stand out in Brazil:

- **Access to technical assistance plays a large role in increasing productivity in both cattle ranching and crop farming, regardless of the scale of production.** Assistance helps less educated farmers make better use of any given input. Its importance for small-scale agriculture in Brazil is heightened by small farmers' poor average educational levels.
- **Learning from peers, especially from those whose land shares similar characteristics, catalyzes technological adoption.** In Brazil, direct planting was more widely adopted in regions where producers had similar soil types, and therefore could more easily learn about the new technique from other nearby farmers with whom they shared production characteristics.
- **Access to formal education** Higher educational levels increase producers' overall ability to learn and implement better agricultural practices. In particular, higher educational levels for small-scale producers significantly increase farm productivity. Evidence also suggests that while specialized training (college education) boosts crop farm productivity, cattle ranching only demands some level of formal education (elementary education) for the diffusion of good practices.

Well-functioning land rental markets

There is clear scope for public policy to improve conditions for the development of more active land rental markets, and thereby help catalyze the conversion of low-productivity to high-productivity land uses.

Land rental markets may increase efficiency of land use by placing more skilled operators on available land. Their capacity to improve land use holds particularly in a setting in which land is used for non-agricultural ends. This is especially relevant for Brazil – given the country's long history of macroeconomic instability, land ownership in Brazil yields non-agricultural benefits, such as hedging against inflation. In this context, an active land rental market offers the means to provide land access to more skilled operators and redistribute land according to its highest-value uses.

Indeed, leasing of land in Brazil is associated with greater farm productivity both for cattle ranching and crop farming. Land rental markets appear to contribute not only to the realization of productivity gains within specific land uses, but also to the acceleration of the conversion of land from low-productivity to high-productivity uses. Municipalities with higher rates of adoption of leasing contracts exhibit greater cattle and crop farm productivities. In addition, municipalities with higher rates of adoption in the Center-West region, which recently embarked on a process of conversion of pasture into cropland, have lower shares of pasture.

In spite of this, **Brazilian land rental markets are underdeveloped as compared with other countries.** Less than 5% of Brazilian agricultural land was under lease or used in partnership in 2006. In contrast, this figure is above 35% and above 65% for Europe and the United States, respectively. The reasons for this are unclear, though likely explanations include the country's lack of well-established property rights, high risk of eviction, and difficulty in enforcing contracts, among others.

Presence of cooperatives

There is mixed evidence on the impacts of cooperatives on agricultural production in Brazil. This is not entirely consistent with the expected benefits of cooperatives. Whether these findings represent a true picture of Brazil or are a result of the unavailability of appropriate data for the

investigation of the impacts of cooperatives remains unknown. More suitable data and analysis are needed to better understand the role cooperatives play in Brazilian agricultural production.

Small-scale farms have less flexibility in the use of basic inputs such as tractors or technicians. Cooperatives in theory serve to overcome this problem, acting as instruments of scale. Once aggregated in cooperatives, small producers can more easily buy large or costly production inputs, they gain bargaining power in negotiations, and the spread of technology is accelerated via centralized access to technical assistance and facilitated diffusion of information. Cooperatives can also enable greater access to credit – in the South and Southeast regions of Brazil, credit cooperatives account for about 8% of financing for agricultural production. In this sense, cooperatives can enable the productivity gains brought about by other factors, such as technological adoption and credit.

However, data on the actual benefits of cooperatives are mixed. In Brazil, association with cooperatives exhibits large regional variation. Cooperatives are associated with productivity gains in large-scale crop farming, but not in large-scale cattle ranching; in small-scale agriculture, they are associated with higher farm productivity only for cattle ranching.

Quality of infrastructure

Indicators of better quality infrastructure are associated with increased productivity in large-scale cattle ranching, large-scale crop farming, and small-scale agriculture in Brazil. There is ample scope for public policy to improve the quality of infrastructure in the country and thereby help boost agricultural productivity.

Agricultural producers depend on infrastructure to reach both upstream and downstream markets. In determining producers' access to inputs and consumers, infrastructure alters the return on agricultural production and affects productivity. In-farm infrastructure – particularly storage capacity – is also relevant to ensure the agricultural product meets requirements concerning quality and timing of delivery.

Despite being one of the most prominent agricultural producers in the world and an important exporter of agricultural commodities, Brazil suffers from poor infrastructure. This imposes a very high cost on agricultural production and thereby reduces agricultural productivity. The country's overall storage capacity is set at 80% of the total harvest, well below the Food and Agriculture Organization recommended level of 120%. Transportation bottlenecks also burden agricultural production. Poor and inefficient roads make transportation costly – carrying a ton of soybean from one of Brazil's leading soybean production municipalities to its point of export is almost three times more expensive as it is to carry the same amount of soybean over a similar distance in the United States. In addition, lacking road infrastructure keeps production from being exported through more cost-effective ports – in some cases, this represents a near twentyfold increase in costs.

Where To Go From Here

This report offers a first look at some of the challenges Brazil faces in its effort to implement a P&P strategy. It identifies key issues affecting environmental protection and agricultural production in the country. **Enhanced understanding about these issues, and especially about the underlying mechanisms driving them, is needed to better tailor the set of policy actions capable of addressing each of them in turn.** An integrated P&P strategy provides such understanding. Yet, its implementation is based on two fundamental components – the regular and frequent monitoring of selected areas that represent key uses of land in Brazil and the creation of a public-private consortium – both of which must be in place prior to advancing the P&P strategy.

The systematic monitoring of selected areas with key land uses plays two major roles. First, it enables the collection of information needed to analyze these areas, which allows for the identification and assessment of potential efficiency gains. Second, it provides an opportunity for experimentation. The empirical testing of the impacts of policy interventions yields evidence on how policies work, what are the driving mechanisms behind their effect, and where there is room for improvement. **It can therefore support the design of more effective public policy.**

It is crucial that monitoring and experimentation efforts focus on relevant and feasible interventions capable of producing tangible results at scale. Therein lies the need for the public-private consortium. This group of actors plays an important part in steering the development and implementation of a P&P strategy, integrating action across key government agencies and leading private firms. **Through a combination of the complementary strengths of its members, the public-private consortium helps validate the identification of representative opportunities for systematic monitoring, determine the scope of the analytical efforts associated with the P&P strategy, formulate possible interventions, and implement experiments.**

A better understanding of regional rural economies and the improved targeting of public policy have the potential to yield significant welfare, protection, and production gains. By promoting the transition into high-productivity, efficient land use at a national scale, a P&P strategy can accelerate the improvements in land use in the Brazilian rural economy. **The implementation of a P&P strategy in Brazil therefore presents itself as a practical means to realize social, economic, and environmental gains, enabling the country to achieve growth of its rural economy alongside enhanced protection of its natural resources.** ■

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Part I

The Production and Protection Strategy

Chapter 1

The Production and Protection Strategy

Chapter Preview

Many countries worldwide struggle to reconcile economic and environmental goals. A Production and Protection (P&P) strategy is an integrated multisectoral approach towards rural land use at a national level aimed at helping nations meet such goals. It enables the identification and assessment of potential land use efficiency gains, and serves as a practical means to realize social, economic, and environmental gains. **By contributing to the design of more effective public policy, a P&P strategy promotes growth in a country's rural economy alongside enhanced protection of its natural resources.**

The implementation of a P&P strategy is based on two fundamental components – **the regular and frequent monitoring of selected areas that represent key uses of land and the creation of a public-private consortium.** The systematic monitoring of selected areas with key land uses enables the collection of information needed to assess potential efficiency gains within these areas, and provides an opportunity for experimentation to support the design of more effective public policy. The public-private consortium, in turn, serves to guide and validate analytical efforts associated with the P&P strategy, thereby ensuring that monitoring and experimentation focus on relevant and feasible interventions capable of producing tangible results at scale. Moreover, through a combination of the complementary strengths of key government agencies and leading private firms, the consortium helps formulate possible interventions and implement experiments.

The chapter starts with an introduction to the concept of a P&P strategy, explaining how it can be used to both assess efficiency of land use at a countrywide level and structure policy efforts. It then discusses the practical details of implementing a P&P strategy.

1.1 Concept

The simultaneous pursuit of sustained economic growth and effective protection of natural resources currently stands as a great challenge to nations worldwide. Rising pressures from increasing global demand for food and climate change risk exacerbate this challenge. The P&P strategy, at its heart, promotes efficient land use – one in which land is put to its highest-value use – to help nations meet both economic growth and conservation goals. It coordinates activities at the national level, with countries integrating land use across multiple economic sectors. In this setting, gains originate from a reallocation of land either across sectors or within them. While efficiency gains occur via the redistribution of land into higher value uses across sectors, productivity gains result from improving land use within sectors, for example, by taking advantage of technical and organizational advances, or by reducing lingering inefficiencies from the past.

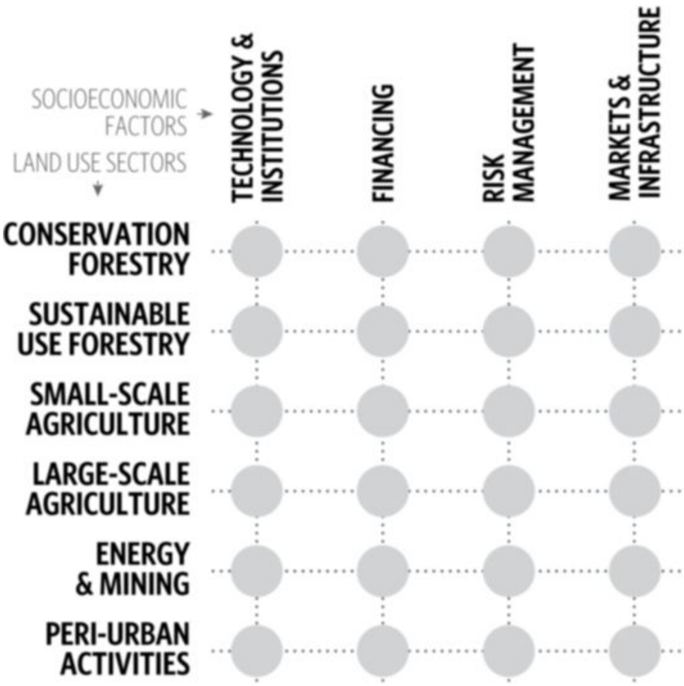
The P&P strategy serves to identify and assess the scope for land use efficiency gains both across and within sectors at a countrywide level, as well as to characterize specific challenges for the realization of such gains in each sector. It takes an integrated approach towards land use, regarding land as an asset with multiple alternative, and at times concurrent, uses – forestry, agriculture, energy, mining, and peri-urban activities.

The P&P matrix

Figure 1.1 presents the P&P matrix, **a graphical representation of the P&P strategy that allows key socioeconomic factors (columns) to be addressed across different land use sectors (rows)**. The relative importance of each sector and the socioeconomic environment vary among countries and regions. In addition to serving as the structural basis for analytical efforts aimed at identifying and characterizing potential efficiency gains, the P&P matrix can also be used to coordinate the participation of public and private agents in the pursuit of a national P&P strategy.

The elements that compose a P&P matrix may present significant overlaps. Consider, for instance, a policy concerning the concession of subsidized credit to small farmers. Although the policy itself is allocated in a single cell in Figure 1.1 (that of financing for small-scale agriculture), its impacts might affect technological uptake (which lies in the technology and institutions column) and its aims might include the promotion of forest conservation (which spans across both conservation and sustainable use forestry sectors). In light of this, analytical efforts can target specific issues in a single sector (cell), characterize the challenges of a given sector (rows), or evaluate policies and actions across sectors (columns). The entire P&P matrix can also be applied to a particular region, either from an analytical standpoint, or from a perspective of policy design and experimentation.

Figure 1.1 The P&P Matrix

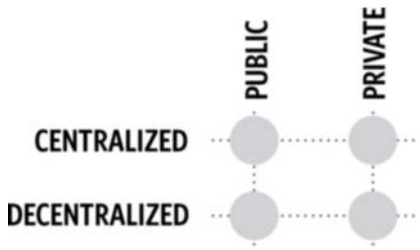


This report provide analytical insights to support P&P efforts in Brazil, focusing on the the two most relevant land uses for the Brazilian rural economy – forestry and agriculture. The P&P matrix in this case is thus restricted to the following four sectors: **forestry, large-scale cattle ranching, large-scale crop farming, and small-scale agriculture**.

Delivery mechanisms for a P&P strategy

The P&P matrix offers a structure within which the potential for land use efficiency gains can be identified and assessed across sectors and socioeconomic aspects. Once this potential has been characterized, however, there remains the question of how to best implement the actions needed to realize the gains. Alternatives include fiscal transfers, policies, and other interventions. Delivery of these elements in a P&P strategy generally takes one of four forms – policies and actions can be provided in a centralized or decentralized fashion, and can be operated by public or private agents (see Figure 1.2). The same goal can often be pursued using a different combination of delivery mechanisms. Take forest conservation in Brazil as an example. The country's Forest Code determines that specific areas within private landholdings be preserved as native vegetation. While the Forest Code establishes mandatory decentralized and private provision of environmental services, the protection of public lands ensures centralized and public provision of the same services.

Figure 1.2 Delivery Mechanisms for a P&P Strategy



The delivery mechanisms depicted in Figure 1.2 are associated with different costs and benefits. The adequacy of each mechanism is context-specific, and will thus depend on the nature and aim of the relevant policy or action. On the one hand, centralization facilitates the coordination of efforts, reduces transaction costs, and offers a higher degree of control over direct and indirect effects of policy action. On the other hand, decentralization offers greater agility and adaptability to regional needs. Similarly, from an operational standpoint, public action often involves institutional restrictions that jeopardize the flexibility and speed of delivery. In addition, public and private interests often differ, particularly regarding situations that are prone to externalities. The public gains from the conservation of natural resources, for instance, might be substantially larger than the private ones.

1.2 Implementation

Tailoring a P&P strategy to a specific country and effectively implementing it requires the continuous identification and assessment of potential barriers, bottlenecks, and challenges. This process is necessarily dynamic and interactive, since the direct involvement of key agents is central to scoping, validating, and implementing P&P efforts. There is room in this endeavor for both public and private actors. In fact, the participation of government agencies and leading private firms is essential to the successful development and implementation of a countrywide P&P strategy. On the one hand, public policy plays a central role in providing incentives and enforcing laws and regulations – the latter is particularly relevant for achieving conservation goals. On the other hand, modern agricultural know-how, as well as supporting financial, risk management, processing, and marketing services, is mostly concentrated in private firms. Both fiscal and market instruments can also be used to deliver positive and equitable incentives for the distribution of gains obtained from sustained economic growth and the protection of natural resources.

Public and private action are often complementary in a P&P strategy. As an example, consider the attractiveness of productivity-boosting efforts. Although it partly depends on institutional incentives being aligned with market-based incentives for individual profit-maximizing behavior, private agents likely play a large role in the development and implementation of high-productivity practices. As land becomes more productive, producers face stronger incentives to clear areas of native vegetation for incorporation into agricultural uses. Herein lies the need for public policy. To ensure that the clearing of native vegetation is curbed, the government must increase clearing costs incurred by producers. This can be achieved through more stringent conservation policies, as well as incentive-based policies that encourage producers to protect native vegetation.

In light of this, we call attention to two fundamental components of a P&P strategy – **the regular and frequent monitoring of selected areas that represent key uses of land and the creation of a public-private consortium** – both of which must be in place prior to advancing the P&P strategy.

The systematic monitoring of selected areas with key uses of land plays two major roles in the development and implementation of a P&P strategy. First, **it enables the collection of valuable data for analyzing such areas, and thereby identifying and assessing the scope for potential efficiency gains in them**. Second, **it provides an opportunity for experimentation**. A first round of data collection serves as the baseline scenario for a given area, and subsequent rounds allow for empirically testing the impacts of interventions. Experimentation can help increase effectiveness of public and private action, yielding empirical evidence on how policies and actions work, what the driving mechanisms behind their effect are, and where there is room for improvement. **The P&P monitoring system must therefore be based on a large-scale data collection effort that aims at building a high-frequency panel of individual or household-level survey data.** This data set should include information on land use, socioeconomic characteristics, local geographic characteristics, and economic decisions. Representative areas for data collection should be chosen based on each country's needs and land use patterns.

Consider, as an example, the financing of agricultural production, Brazil's main agricultural policy. Little is known about how changes in income, agricultural prices, or weather affect producers' use of resources and investment decisions. In theory, financial instruments increase producers' abilities to deal with such changes without having to alter their production decisions as much – by allowing producers to smooth out shocks, these instruments make their decisions less vulnerable to shocks. Data collected through the systematic monitoring of representative areas could shed light on how effectively existing instruments do so. Moreover, these data could also enable the assessment of how formal financial instruments interact with informal local instruments. Enhanced knowledge about these underlying mechanisms is important to improve policy design.

For P&P efforts to be effective, it is crucial that monitoring and experimentation focus on relevant and feasible interventions capable of producing tangible results at scale. Therein lies the need for the public-private consortium. This group of actors plays an important part in steering the development and implementation of a P&P strategy, integrating action across key government agencies and leading private firms. Through a combination of the complementary strengths of its members, **the public-private consortium helps validate the identification of areas for systematic monitoring, determine the scope of the analytical efforts associated with the P&P strategy, formulate possible interventions, and implement experiments.**

A better understanding of regional rural economies and the improved targeting of public policy have the potential to yield significant welfare, protection, and production gains. By promoting the transition into high-productivity, efficient land use at a national scale, a P&P strategy accelerates improvements in rural land use. Moreover, it supports the design of more effective public policy. **The implementation of a P&P strategy therefore presents itself as a practical means to realize social, economic, and environmental gains, enabling nations to achieve growth of their rural economy alongside enhanced protection of their natural resources.**

Chapter 2

Overall Potential for Production and Protection Strategy in Brazil

Chapter Preview

Brazil plays an important part in the global effort to protect natural resources, as well as in the world market for agricultural products. Moreover, increasing efficiency of land use in Brazil contributes to the achievement of both economic and environmental national goals. Taking this as a starting point, this chapter assesses the overall potential for implementing a Production and Protection (P&P) strategy in Brazil.

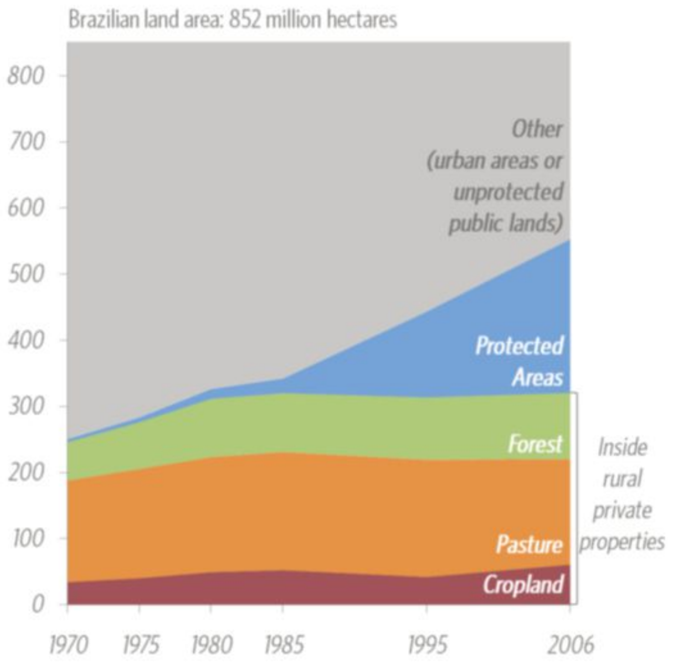
There is significant variation in agricultural productivity both across and within Brazilian regions. Great within-region variation indicates there is ample room to increase Brazilian agricultural production via productivity gains, at no apparent cost to the protection of natural resources. While geographical factors explain about a third of the total variation in Brazilian agricultural productivity, non-geographical factors including access to finance, technological diffusion, rental markets, cooperatives, and quality of infrastructure account for an important part of the remaining variation. The non-geographical variation in productivity determines the potential for realizing productivity gains.

The chapter starts with an introduction to land use in Brazil in Section 2.1 that looks at both current and past distributions of land. Section 2.2 presents evidence attesting to the variation in agricultural productivity across and within Brazilian regions. Finally, Section 2.3 empirically explores the association between agricultural productivity and the four socioeconomic aspects of the P&P matrix – technology and institutions, finance, risk, and infrastructure. The appendix at the end of the chapter provides theoretical and methodological details for this empirical investigation.

2.1 Land Use in Brazil

Brazil has a vast territory (852 million hectares), a wealth of natural resources, and an important agricultural sector. Its overall land use distribution, according to the last year for which countrywide agricultural data was available, reflects roughly 26% agricultural lands, 12% forestland inside private property, 27% protected native vegetation, and 35% other uses including urban areas and unprotected native vegetation in public lands (see Figure 2.1).[1] This distribution has changed over the past four decades, with a relatively small expansion of agricultural land (from 22% of total national territory in 1970 to 27% in 2006) and private forestland (from 7% to 12%). There was a much larger expansion of protected areas during this period (from 1% to 27%), driven by policy shifts.

Figure 2.1 Land Use in Brazil, 1970–2006



Notes: The figure shows land use composition for total Brazilian territory from 1970 through 2006. Agricultural data is only available for the labelled years. Data sources: FUNAI (2013), IBGE (2013a), and MMA (2013).

Forestland

The country saw a vast expansion of protected territory since the mid-1980s. In 2006, protected areas totaled over 230 million hectares – more than ten times the area they covered in 1985. Private forestland accounted for another 100 million hectares. Combined, protected areas and forestland inside private property amount to nearly 40% of Brazil's total area. Unprotected forests in public lands further increase the share of Brazilian territory covered by native vegetation. These forests are important for their environmental value – the Amazon alone accounts for nearly 20% of the freshwater feeding into the world's oceans, holds unique biodiversity, and is an important carbon sink. They are also important for their economic value for present and future generations, especially as a sustainable forestry sector comes into development. In all, this highlights Brazil's great potential and responsibility for environmental protection.

Pasture and cropland

Cattle ranching has long been Brazil's most land-intensive agricultural activity, though the share of agricultural land devoted to cattle ranching has fallen over recent years, making way for a rise in the share of cropland. In 2006, pasture occupied nearly 75% of the country's agricultural lands, while crop farming occupied the remaining 25%. This amounted to about 160 million hectares of pasture and 60 million hectares of cropland, or 220 million hectares of agricultural land.

Today, Brazil stands as a key player in the global effort to protect natural resources, but also occupies a relevant position in the market for agricultural commodities. Hence, promoting efficient land use in Brazil not only mitigates the impacts of climate change and protects natural resources, but also helps meet rising food demand challenges ahead. The pursuit of a P&P strategy presents the challenge of promoting growth of agricultural production via the adoption of high-productivity practices. In this context, putting land into its highest-value uses requires consideration of the various alternative uses of land, including those that yield environmental benefits.

The remainder of this chapter focuses on the production component of a P&P strategy, using data from six Brazilian Agricultural Censuses covering the 1970 through 2006 period to unveil empirical evidence that underlines the potential for realizing efficiency gains within the Brazilian agricultural sector. This discussion has important implications for both agricultural

[1] The term "forest" is used throughout this report to refer to all types of natural vegetation in Brazil's six biomes, and not only to tropical forests.

production and environmental production in Brazil – the evidence suggests **there is room to increase Brazilian agricultural production via productivity gains, without having to expand production into forested land**. We address the protection component of a P&P strategy in more detail in Chapter 3.

2.2 Variation in Agricultural Productivity

This section investigates regional variation in Brazilian agricultural productivity to assess the country's overall potential to increase agricultural production while ensuring the protection of its natural resources.

Variation in agricultural productivity can occur both across and within a country's regions. Differences in productivity across regions might result from differences in geographical conditions affecting agricultural output, such as soil quality, or from idiosyncratic events, such as extreme local weather. In fact, efficient resource allocation implies that land is being put to its highest-value use, so if there is any variation in productivity across regions, it is due only to variation in geographic conditions and idiosyncratic events.

Under perfectly efficient land use, there would be no within-region variation in productivity, assuming all areas within a region have similar geographic conditions. Any within-region variation in productivity would mean that areas in the same region did not have equal access to productivity drivers, that is, that there were some socioeconomic factor differences that caused differences in productivity within that region.

The presence of within-region variation in productivity is therefore indicative of inefficient land use and points towards potential efficiency gains. Moreover, the socioeconomic factors associated with differences in productivity identify the aspects in which there is scope for policy action.

Understanding the nature of existing relationships between agricultural productivity and socioeconomic factors is key for the design of public policies supported by a P&P strategy. In particular, within-region variation indicates that there is room to increase agricultural production via productivity gains, instead of through the expansion of land (often, forestland) for production. By tackling the barriers that prevent the realization of these productivity gains, policy can promote growth in production alongside the protection of natural resources.

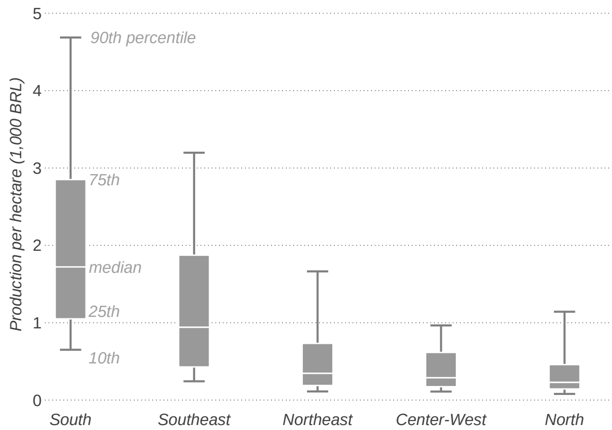
2.3 Evidence from Brazil

We tested for the presence of a systematic relationship between agricultural productivity and socioeconomic factors in Brazil, using data from the 2006 Brazilian Agricultural Census, the last year for which countrywide agricultural data was available. Taking the value of agricultural output per hectare in Brazilian municipalities as the measure of productivity, we examined productivity variations within and across sectors. Chapters 4 through 6 look at each agricultural sector separately.

Inefficient land use

We start with an examination of overall regional productivity variation. Figure 2.2 plots the range of agricultural productivity for the five Brazilian regions, showing there is variation both across and within regions.

Figure 2.2 Variation in Agricultural Productivity, 2006



Notes: The figure shows the variation in productivity measured as the value of agricultural output per hectare at the municipality level, by region. The upper whiskers show the 90th percentiles of municipalities' productivity; the upper box edges show the 75th percentiles; the white marks show the medians; the lower box edges show the 25th percentiles; and the lower whiskers show the 10th percentiles. Data source: IBGE (2013a).

Across-region variation is substantial. The highest regional median value for agricultural productivity (1,721 BRL/hectare in the South), for example, is more than seven times greater than the lowest regional median productivity (229 BRL/hectare in the North).[2] As discussed before, this variation in productivity may result from differences in geographical characteristics across Brazilian regions, as well as from idiosyncratic regional factors.

[2] BRL stands for Brazilian *reais*, the local currency in Brazil.

Large within-region variation is also apparent in Figure 2.2. In the North, for instance, municipalities in the bottom quarter of the productivity distribution have agricultural productivities below 144 BRL/hectare, while those at the top quarter of the distribution have agricultural productivities above 459 BRL/hectare. Variation within a given region suggests there are factors that significantly constrain productivity across municipalities belonging to a same region.

It's important to highlight that, in Brazil, the assumption of similar geographical conditions within regions does not hold in its entirety. Because the country's five regions are very large, there is substantial geographical variation across municipalities in a same region. Part of the within-region variation shown in Figure 2.2 may therefore be attributed to differences in geographical conditions across municipalities. Yet, as we show in the next section, we find evidence that socioeconomic factors affect agricultural productivity beyond variation in geographical conditions. This result indicates that **there is significant non-geographical variation in productivity in Brazil**.

These findings provide suggestive evidence of inefficient land use in Brazil. Realizing efficiency gains in this context hinges on identifying the factors that affect agricultural productivity in Brazil and tailoring policy to act upon these factors.

Key factors affecting agricultural productivity

Having established that there is room for efficiency gains within the Brazilian agricultural sector, we follow with an investigation of the existence of a systematic relationship between agricultural productivity and the socioeconomic aspects listed as columns of the P&P strategy matrix (see Figure 1.1) – technology and institutions, financing, risk management, and infrastructure.

We chose these specific socioeconomic aspects for two reasons. First, these aspects emerged as potentially relevant to productivity in a review of existing literature and interviews with stakeholders and experts in the field. Second, these aspects are quantifiable – to varying degrees – through Brazil's Agricultural Census.

We begin to quantify the variation in agricultural productivity into its geographical and non-geographical components here. Details on the methodology used, as well as full empirical results can be found in the appendix at the end of the chapter.

Our findings indicate that geographical factors explain about one third of total variation in Brazilian agricultural productivity (see Table 2.1 in the appendix). Key non-geographical factors – namely, technological adoption, access to technical assistance, land rental markets, association with cooperatives, access to financial instruments for credit and risk management, and quality of infrastructure – account for an important part of the remaining variation (see Table 2.2 in the appendix). We discuss each of these factors in turn.

Geographical conditions

We account for six different measures of geographical conditions that may affect productivity – soil type, rainfall, temperature, altitude, distance to the equator, and distance to the sea. Combined, these geographical conditions explain 37% of the observed variation in agricultural productivity across municipalities. This finding suggests that, as expected, **natural factors have a large impact on agricultural production**.

Technology and institutions

The use of technology in agricultural production is associated with greater productivity in Brazil. Once we have accounted for differences in geographical conditions, the adoption of established agricultural practices – namely, irrigation, direct planting, rotational grazing, application of lime, and other specific agricultural methods – explains 15% of the variation in agricultural productivity observed in Brazil.

Understanding the channels through which new technologies spread contributes to the development of a P&P strategy, since it enables the identification of specific policy action opportunities. Three key channels stand out. First, access to technical assistance seems to play a significant role in increasing productivity. Assistance helps less educated producers make better use of any given resource. Its importance in Brazil is likely heightened by poor average educational levels, particularly among small-scale producers. Second, learning from peers, especially from those whose land shares similar characteristics, catalyzes technological adoption. Third, access to formal education, which is expected to increase a producer's overall ability to learn and implement better agricultural practices. This is evidenced by the finding that producers' educational levels significantly affect farm productivity.

Association with cooperatives are an alternative way of gaining access to knowledge and information on better practices. Consider small-scale farms, for example. Such farms typically have less flexibility in the use of basic resources such as tractors or technicians, due to restrictions imposed by scale. In theory, cooperatives serve to overcome this problem, acting as instruments of scale. Once aggregated in cooperatives, small producers can more easily buy large or costly production inputs, they gain scale and bargaining power in negotiations, and the spread of technology is accelerated via centralized access to technical assistance and facilitated diffusion of information. Cooperatives can also enable greater access to credit. In this sense, cooperatives can help catalyze the productivity gains brought about by other factors. Results show that **municipalities with greater shares of producers associated with cooperatives have higher average agricultural productivity**.

Land rental markets are also an important institutional factor affecting productivity. Such markets may increase efficiency of land use by placing more skilled operators on available land. The capacity to improve land use holds particularly in a setting in which land is used for non-agricultural ends. This is especially relevant for Brazil – given the country's long history of macroeconomic instability, land ownership in Brazil yields non-agricultural benefits, such as hedging against inflation. In this context, an active land rental market offers the means to provide land access to more skilled operators and redistribute land according to its highest-value uses. Indeed, **leasing of land in Brazil is associated with greater farm productivity. In spite of this, Brazilian land rental markets are underdeveloped in comparison with other countries.** Less than 5% of Brazilian agricultural land was under lease or used in partnership in 2006. In contrast, this figure is above 35% and above 65% for Europe and the United States, respectively (Assunção, 2008). The reasons for this are unclear, though likely explanations include Brazil's lack of well-established property rights, high risk of eviction, and difficulty in enforcing contracts, among others.

Financing and risk management

Agricultural production worldwide strongly depends on financing. It is characterized by relatively long productive cycles brought about by the maturing of livestock, or necessary intervals between planting and harvesting. These long productive cycles, combined with high exposure to weather and price risks render access to financial instruments crucial to enable rural producers to smooth out shocks. Credit and risk management are therefore very important to agricultural production.

In a perfectly operating economy, investors would be able to smooth out idiosyncratic events and provide producers with the resources they need for production. However, credit markets typically suffer from informational problems that lead to credit rationing – lenders don't know if borrowers will pay back the loan, they aren't able to properly monitor borrowers' behavior and incentives, and they can't know for sure who they are lending funds to. Under rationing, the unavailability of credit can become a major barrier to agricultural productivity, especially for farming that requires large capital expenditures. Empirical findings corroborate this rationing scenario. It is clear that **credit significantly affects agricultural production decisions in Brazil** – about 20% of the regional variation in Brazilian agricultural productivity is associated with credit availability. This result suggests that greater access to credit could improve productivity. However, the specific channels through which credit affects productivity are unclear. Detailed data on agricultural production and access to credit at an individual (farm) level would shed light on these channels.

In addition, farmers with limited access to risk management instruments might be led to invest less than they would in an ideal setting as a means of reducing the volatility of their cash flows. Using rain volatility as a measure of risk, our analysis shows that **greater risk is associated with lower agricultural productivity across Brazilian municipalities**. This effect is, however, fairly small. Two explanations can account for the magnitude of this effect. On the one hand, rainfall might not be the most relevant risk for farming in Brazil. On the other hand, limited access to financial instruments may hinder technological adoption that increases risk exposure.

Infrastructure

Agricultural producers depend on infrastructure to reach both upstream and downstream markets. In determining producers' access to inputs and consumers, infrastructure alters the return on agricultural production and affects productivity. In-farm infrastructure – particularly storage capacity – is also relevant to ensure that agricultural products meet requirements concerning quality and timing of delivery.

Despite being one of the most prominent agricultural producers in the world and an important exporter of agricultural commodities, Brazil suffers from poor infrastructure. This imposes a very high cost on agricultural production and thereby reduces agricultural productivity. Indeed, shorter distances to state capitals and ports, which serve as indicators of better quality infrastructure, are associated with increased productivity in Brazil.

Overall, these non-geographical factors are key drivers of agricultural productivity in Brazil. In light of this, they represent important opportunities for policy action aiming at promoting agricultural growth via productivity gains and simultaneously protecting natural resources. **A P&P strategy offers a means of structuring policy to address each of these socioeconomic factors and tailoring it to fit local needs.** The realization of efficiency gains through productivity increases supports Brazil in its effort to achieve concurrent economic and environmental goals.

Appendix - Analyzing Agricultural Productivity

This appendix describes the methodology for the analysis presented in Chapter 2, based on Assunção and Braido (2007). We define a benchmark against which to discuss the role of policies.

Theoretical Framework

We consider a rural economy in which farmers, indexed by i, use a Cobb-Douglas production function with the following specification:

$$Y_i = A_i T_i^{\alpha_t} K_i^{\alpha_k} L_i^{\alpha_l} \exp(\varepsilon_i); \qquad (2.1)$$

where Y_i represents the total output; T_i is the farm size; K_i and L_i represent the amount of nonlabor and labor input used; A_i is a technological factor that also accounts for observable household and land characteristics as well as specific effects associated with different municipalities and crops grown; and ε_i is an error term accounting for unobserved and idiosyncratic determinants of the output such as weather shocks and infestations. The parameters α_t, α_k and α_l represent the output elasticity with respect to each input.

By multiplying Y_i, K_i and L_i by their respective prices (namely, p, r, and w), we can represent the production function in monetary units, as follows:

$$y_i = a_i T_i^{\alpha_t} k_i^{\alpha_k} l_i^{\alpha_l} \exp(\varepsilon_i); \qquad (2.2)$$

where $y_i = pY_i$ represents the value of the output; $k_i = rK_i$ and $l_i = wL_i$ are the value of nonlabor and labor inputs (respectively); and $a_i = \frac{A_i p}{(r)^{\alpha_k}(w)^{\alpha_l}}$ is a price-adjusted technological term.

Consider now a competitive environment with no externality and constant return to scale, i.e., $\alpha_t = (1 - \alpha_k - \alpha_l)$. For any arbitrary plot size, farmers would maximize the expected profit, such that plot i's input choices would solve:

$$\max_{k_i, l_i} E\left(a_i T_i^{\alpha_t} k_i^{\alpha_k} l_i^{\alpha_l} \exp(\varepsilon_i) - k_i - l_i\right). \qquad (2.3)$$

The optimal amount of nonlabor and labor inputs would be then given by:

$$k_i^* = T_i \left(\alpha_k^{(1-\alpha_l)} \alpha_l^{\alpha_l} a_i E(\exp(\varepsilon_i))\right)^{\frac{1}{1-\alpha_k-\alpha_l}}; \qquad (2.4)$$

$$l_i^* = T_i \left(\alpha_l^{(1-\alpha_k)} \alpha_k^{\alpha_k} a_i E(\exp(\varepsilon_i))\right)^{\frac{1}{1-\alpha_k-\alpha_l}} \qquad (2.5)$$

Equation (2.2) can be written as:

$$\frac{y_i}{T_i} = (\lambda a_i)^{\frac{1}{1-\alpha_k-\alpha_l}} \exp(\varepsilon_i); \qquad (2.6)$$

where $\lambda = (\alpha_k)^{\alpha_k}(\alpha_l)^{\alpha_l}\left[E(\exp(\varepsilon_i))\right]^{(\alpha_k+\alpha_l)}$.

Equation (2.6) plays a central role in our empirical analysis, establishing a benchmark to evaluate the role for policies. In the absence of frictions, the term a_i should be affected only by geographical characteristics. This is the case in which there is no role for public policies. However, market frictions might constraint the agricultural production either through the technological diffusion or by affecting input choices. A version of equation (2.6) can be shown to hold at the aggregate level.

Empirical Results

We now implement an empirical assessment of equation (2.6), estimating the following specification:

$$ln\frac{y_i}{T_i} = \beta_0 + \beta_1 G_i + \beta_2 X_i + \varepsilon_i, \qquad (2.7)$$

where G_i is a vector of geographical characteristics and X_i is a vector of other socio-economic factors. If equation (2.6) holds with no market frictions, we should observe:

$$\beta_0 = \frac{1}{1-\alpha_k-\alpha_l}\lambda; \beta_1 = \frac{1}{1-\alpha_k-\alpha_l} \text{ and } \beta_2 = 0. \qquad (2.8)$$

Using data from the 2006 Brazilian Agricultural Census, we estimate equation (2.7) for Brazilian municipalities. Results are shown in Tables 2.1 and 2.2.

Table 2.1: Brazilian Agricultural Productivity by Geographical Aspects, 2006

	estimate	std. error
Rain	0.097***	(0.022)
Rain^2	-0.001**	(0.001)
Temperature	-0.005	(0.083)
Temperature^2	-0.002	(0.002)
Altitude	0.017**	(0.008)
Log(distance to sea)	-0.268***	(0.020)
Log(distance to equator)	0.167***	(0.050)
Observations	3,729	
R-squared	0.372	

Notes: The dependent variable is the log of productivity, measured as gross revenues per hectare. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 2.2: Brazilian Agricultural Productivity by Economic Aspects, 2006

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log(distance to state capital)	-0.091***						
	(0.027)						
Log(distance to ports)	-0.295***						
	(0.033)						
Share of area with technical assistance		0.927***					
		(0.091)					
Share of area producer is associated to cooperative		0.643***					
		(0.080)					
Share of area settlements			-0.477				
			(1.050)				
Share of area producer is lessee			4.667***				
			(0.856)				
Share of area producer is partner			4.116***				
			(1.384)				
Share of area producer is occupant			0.336				
			(0.758)				
Share of area producer is literate				-1.144***			
				(0.389)			
Share of area producer completed elementary school				0.616**			
				(0.297)			
Share of area producer completed high school				-0.089			
				(0.341)			
Share of area producer completed college				0.874***			
				(0.317)			
Share of area with specific agricultural method					0.558***		
					(0.138)		
Share of area with irrigation					0.510***		
					(0.136)		
Share of area with Direct Planting System					0.281***		
					(0.100)		
Share of farmers using rotational grazing					-0.242***		
					(0.074)		
Share of farmers using lime in soil					2.070***		
					(0.143)		
Log(Financing per hectare)						0.500***	
						(0.015)	
Rain volatility							-0.004***
							(0.001)
Observations	3,696	3,475	691	1,973	1,538	3,727	3,729
R-squared	0.402	0.425	0.428	0.371	0.527	0.583	0.375
Control for geographic conditions	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	No	No	No	No	No	No
F-test	61.774	137.525	11.456	13.393	74.007	1170.775	10.544
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.001

Notes: The dependent variable is the log of productivity, measure as gross revenues per hectare. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Part II

Protection

Chapter 3

Forestry

Chapter Preview

Brazil made great strides in conservation of forestland over the past decade. Today, the country has a relatively consolidated institutional framework and well-established instruments for the protection of natural resources in public lands. Yet, challenges remain in the protection of native vegetation cleared in small increments, on private property, and with Brazil's ecosystems beyond the Amazon, as well as in the development of a sustainable forestry sector.

The first of these challenges is **combating small-scale Amazon deforestation**. Once driven by large-scale forest clearings, Amazon deforestation is now occurring in small increments. This is likely a consequence of Brazil's limited technical capacity to track small-scale deforestation. Further reductions in Amazon deforestation require improving existing monitoring techniques to adequately deal with small-scale forest clearings. **Improving enforcement of environmental regulation within private rural landholdings** is also important. The new Forest Code establishes the regulatory framework for environmental conservation in private lands, and the Rural Environmental Registry provides the key instrument for enforcing this framework. Although both framework and instrument are in place, effectively using the Rural Environmental Registry to implement the Forest Code remains a challenge. Brazil must also strive to **improve protection of natural resources in all of its ecosystems**. This should be done by extending Amazon monitoring and law enforcement efforts countrywide, but also through the adoption of incentive-based action that promotes preservation. Finally, the country faces challenges in **developing a sustainable forestry sector and advancing market-based incentives for the protection of natural resources**. Efforts aimed at promoting such actions in Brazil are still at very early stages.

The chapter starts with an overview of forest land cover in Brazil in Section 3.1. It then presents the institutional background determining the protection of native vegetation within both public and private lands in Section 3.2. The remainder of the chapter discusses some of the challenges Brazil faces in its effort to improve the protection of native vegetation and develop a sustainable forestry sector. Section 3.3 looks at what is needed to better understand, and thereby more effectively tackle, each of these challenges, with particular attention given to aspects concerning environmental institutions, technology, financing, risk, and infrastructure. Finally, Section 3.4 outlines key policy implications.

3.1 An Overview of Brazilian Native Vegetation

This section presents an overview of forest cover in Brazil.[1] National conservation efforts have concentrated on the Amazon over recent years, contributing to a significant reduction in deforestation. This report draws lessons from and identifies challenges based on Brazil's experience with combating deforestation in the Amazon.

Figure 3.1 Brazilian Biomes

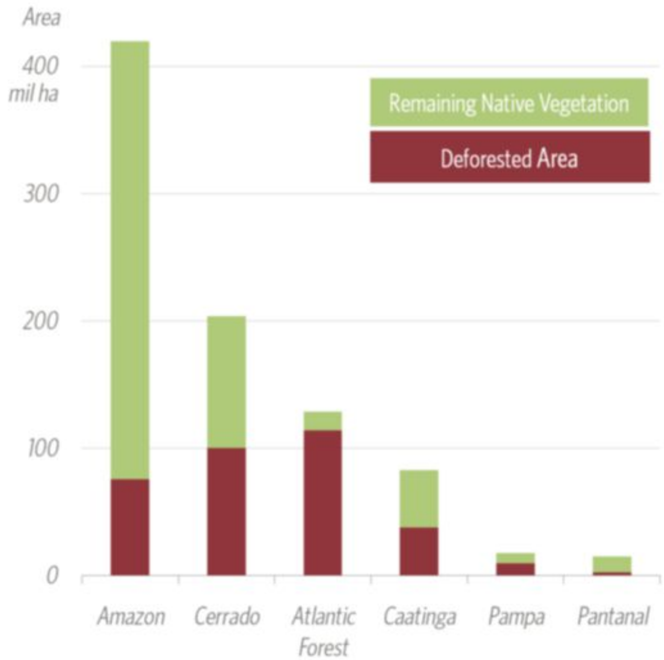
Notes: The map shows the division of Brazil's national territory into its six biomes. The figures indicate total biome area in million hectares. Data source: MMA (2013).

Brazil's vast territory is divided into six biomes (see Figure 3.1), all of which have seen the clearing of native vegetation to a lesser or greater extent (see Figure 3.2). Historically, the Atlantic Forest has suffered the most deforestation in both absolute and relative terms, having been depleted of almost 90% (113 million hectares) of its native vegetation. The Cerrado and Amazon biomes are not far behind – to date, over 100 million hectares of native Cerrado vegetation and over 75 million hectares of native Amazon forest have been cleared. Given these biomes' very large sizes, about 50% of the Cerrado and 80% of the Amazon remain covered by native vegetation despite their exposure to extensive deforestation.

[1] The term "forest" is used throughout this report to refer to all types of natural vegetation in Brazil's ecosystems, and not only to tropical forests.

Throughout the past decade, Brazilian conservation policy efforts focused mostly on combating deforestation in the Amazon biome. The vast majority of Brazil's protected areas, in both absolute and relative terms, are found in the Amazon – in 2000, less than a third of the Amazon biome was under public protection; today, protected areas cover nearly half of it.[2] This did not happen by chance. Brazil holds about 60% of the Amazon Forest, the world's largest rainforest. Native Amazon vegetation originally occupied over 400 million hectares of Brazilian territory – an area equivalent to almost half of continental Europe. In addition to holding unique biodiversity and about 20% of the fresh water feeding into the Earth's oceans, the Amazon is also an important carbon sink. It therefore plays a central role in maintaining environmental equilibria at both regional and global levels.

Figure 3.2 Accumulated Deforestation and Remaining Native Vegetation in Brazilian Biomes

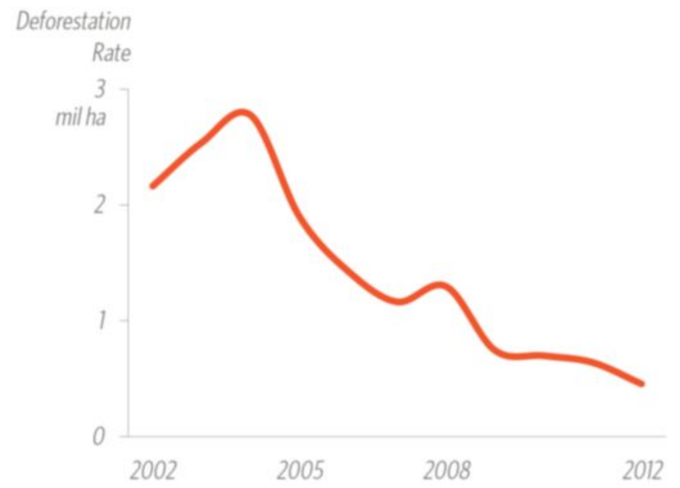


Notes: The figure shows total deforested area and remaining native vegetation by biome. Information was collected based on the date of the latest available per-biome estimates for total deforestation: 2009 for the Caatinga, the Pampa, and the Pantanal; 2010 for the Cerrado and the Atlantic Forest; and 2011 for the Amazon. Data sources: FUNAI (2013), IBGE (2013c), and MMA (2013).

[2] Protected areas currently extend over 25% of Brazilian territory. While nearly 50% of the Amazon biome is under protection, protected areas cover about 11% of the Cerrado, and less than 10% of the Atlantic Forest, the Caatinga, the Pampa, and the Pantanal (MMA, 2013).

Yet, over recent decades, the Brazilian Amazon has been threatened by intense forest clearing activity. The region has long been the world's most active agricultural frontier in terms of forest loss and CO_2 emissions (FAO, 2006). In Brazil, the conversion of forest area into agricultural land has accounted for over 75% of the country's total net CO_2 emissions (MCT, 2010). From a global perspective, deforestation and biomass decay, in large part originating from the clearing of tropical forests, have contributed almost 20% of recent global greenhouse gas emissions (IPCC, 2007; Stern, 2008; MMA, 2012).

Figure 3.3 Amazon Deforestation Rate, 2002–2012



Notes: The figure shows the deforestation rate for the Brazilian Legal Amazon from 2002 through 2012. The Legal Amazon is a socio-geographic division of Brazil composed of the western territory of the state of Maranhão and the entire territory of the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, and Tocantins. It encompasses all of the Amazon biome, plus a part of the Cerrado biome. The Amazon deforestation rate only accounts for the clearing of native Amazon vegetation. Data source: INPE (2013).

Interestingly, Amazon forest clearings have slowed significantly in recent years (see Figure 3.3). **The Brazilian Amazon deforestation rate escalated in the early 2000s, but after peaking at over 2.7 million hectares in 2004, decreased sharply to about 460 thousand hectares in 2012.** The economic literature has long sought to identify the key drivers of tropical deforestation. Studies have documented the impact of long-run economic drivers of deforestation, such as population pressures, income level and economic growth, soil quality, and climate.[3] The influence of factors affecting individual-level forest clearing decisions has also received significant attention in the literature, which has identified rising agricultural output prices, rural credit, road building, and tenure insecurity as some of the more immediate causes of deforestation.[4] Looking specifically at the 2000s deforestation slowdown phenomenon, Assunção et al. (2012) show that declining agricultural output prices helped contain the pace of forest clearings, but that **conservation policies introduced in the second half of the 2000s also significantly contributed to curb Amazon deforestation**.

3.2 Recent Conservation Policy

This section introduces the institutional context for current Brazilian conservation policy, providing an overview of key recent changes.

In Brazil, the protection of natural resources is regulated by a large set of legislative measures that are generally overseen by the Brazilian Ministry of the Environment. Legislation concerning protection within public and private spheres underwent significant revisions over the past years.

Public Protection

The Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (*Plano de Prevenção e Controle do Desmatamento na Amazônia Legal*, PPCDAm), the pivotal conservation policy effort of the mid-2000s, marked the beginning of a novel approach towards combating deforestation in the Brazilian Amazon. Launched in 2004, it integrated actions across different government institutions and proposed innovative procedures for monitoring, environmental control, and territorial management. The operational project for the PPCDAm consisted of a large set of strategic conservation measures to be implemented and executed as part of a new collaborative effort between federal, state, and municipal governments, alongside specialized organizations and civil society. The project focused on three main areas: (i) monitoring and law

[3] Angelsen and Kaimowitz (1999) and Barbier and Burgess (2001) provide comprehensive surveys of this literature through the late 1990s. For a non-exhaustive list of examples, see: Cropper and Griffiths (1994); Panayotou and Sungsuwan (1994); Chomitz and Gray (1996); Barbier and Burgess (1996); Cropper et al. (1997); Pfaff (1999); Chomitz and Thomas (2003); Foster and Rosenzweig (2003).

[4] Among others, see: Reis and Margulis (1991); Reis and Guzmán (1994); Panayotou and Sungsuwan (1994); Chomitz and Gray (1996); Barbier and Burgess (1996); Pfaff (1999); Pfaff et al. (2007); Araujo et al. (2009).

enforcement; (ii) territorial management and land use; and (iii) promotion of sustainable practices.

Strengthening of monitoring and law enforcement

The PPCDAm promoted stricter environmental monitoring and law enforcement through a series of policy efforts.

- **Greatly enhanced Amazon law enforcement capacity due to the introduction of satellite-based monitoring of forest clearing activity.** The main driving force behind stricter monitoring and law enforcement, the Real-Time Detection of Deforestation (*Detecção de Desmatamento em Tempo Real*, DETER) system captures and processes georeferenced imagery on Amazon forest cover in 15-day intervals. These images are used to identify deforestation hot spots and target law enforcement efforts. Prior to the activation of the satellite-based system, Amazon monitoring depended on voluntary reports of threatened areas, making it very difficult for law enforcers to identify and access deforestation hot spots in a timely manner. With the adoption of DETER, law enforcers were able to better identify and more quickly act upon areas afflicted by illegal deforestation.
- **Improved qualification of law enforcement personnel.** The Brazilian environmental police authority established stricter requirements in its recruitment process and provided more specialized training of law enforcers.
- **Institutional changes that brought greater regulatory stability to the administrative processes for the punishment of environmental crimes.** The passing of Presidential Decree 6,514 in 2008 reestablished directives for the investigation and sanctioning of environmental infractions. The decree regulated the use of sanctions including fines, embargoes, and seizure of production goods, tools, and materials.
- **Creation of the priority municipalities list.** Presidential Decree 6,321, signed in 2007, established the legal basis for singling out municipalities with intense deforestation activity and taking differentiated action towards them. These municipalities, selected based on their recent deforestation history, were classified as in need of priority action to prevent, monitor, and combat illegal deforestation. In addition to concentrating a large share of monitoring and law enforcement efforts, priority municipalities became subject to a series of administrative measures that did not necessarily stem from law enforcement policy. Examples include harsher licensing requirements for private landholdings, revision of private land titles, and economic sanctions applied by agents of the commodity industry.

Conditioning of rural credit

Published in 2008, National Monetary Council Resolution 3,545 conditioned the concession of rural credit for use in the Amazon biome upon presentation of proof of borrowers' compliance with environmental regulations. All official credit agents – public banks, private banks, and credit cooperatives – were obligated to abide by the new rules. The conditioning measures of the novel rural credit policy were subject to a series of qualifications that loosened the severity of the new credit constraints, particularly for small-scale producers, who benefited from partial or complete exemptions from the resolutions' requirements.

Expansion of protected territory

The creation of protected areas gained significant momentum under the PPCDAm. This was at least partly due to the Ministry of the Environment's new protection strategy, which overtly adopted the strategic placement of protected areas to act as shields against rising deforestation pressures. A large share of these newly-created areas were concentrated in the central region of the Amazon biome as a means of blocking forest clearing activity moving in from the agricultural expansion frontier.[5]

What role did the PPCDAm's main policy efforts play in the 2000s Amazon deforestation slowdown? Recent analysis indicates that **stricter monitoring and law enforcement appears to have contributed most to curb forest clearings**. In an assessment of the relative impact of the strengthening of environmental monitoring and law enforcement, Assunção et al. (2013a) show that

[5] The agricultural expansion frontier in the Amazon is commonly referred to as the Arc of Deforestation, an area that concentrates a large share of recent forest clearing activity.

an increase in the intensity of law enforcement in a given year significantly reduces forest clearings the following year.[6] The estimated deterrent effect is remarkable – had there been no environmental monitoring and law enforcement in the Amazon biome, total deforested area from 2007 through 2011 would have been over three and a half times greater than what was actually observed during this period. Moreover, the authors find that increased intensity of law enforcement had no significant immediate impact on municipality-level agricultural production. The magnitude of the estimated policy impact suggests that the 2000s Amazon deforestation slowdown was largely driven by the deterrent effect of improvements in environmental monitoring and law enforcement.

Yet, not all aspects of the PPCDAm were as fruitful as its monitoring and law enforcement endeavors. The plan is regarded as having been considerably less successful in advancing its two other areas of focus – territorial management and land use, and promotion of sustainable practices (Maia et al., 2011b). In its effort to establish a Production and Protection (P&P) strategy, Brazil currently faces numerous challenges in addressing these lacking areas and developing a sustainable forestry sector.

Private Protection

While public protection of native vegetation is governed by a variety of legislative measures, the protection of natural resources inside private landholdings is essentially regulated by the Brazilian Forest Code. In particular, the code determines the legal requirements regarding the establishment of legal reserves and areas of permanent protection. These constitute areas that must, by law, be preserved as native vegetation within private properties.

Increasing demand for agricultural output generated rising political pressure that pushed for a revision of the Forest Code (Soares-Filho, 2012). After over a decade of debate, a new Forest Code was sanctioned in 2012, arguably loosening environmental requirements for the private landholder. The basic requirements for legal reserves, which vary across biomes, are preserved in the new code – private properties in the Amazon biome are required to keep 80% of their total landholding area covered by native vegetation; for properties within the Legal Amazon but in the Cerrado biome, the share of legal reserves falls to 35%; for all other areas, it is set at 20%. Yet, the 2012 Forest Code introduced new regulations concerning legal reserves, including a reduced 50% requirement for properties in Legal Amazon municipalities with over half of their territory under protection, and the possibility to count areas of permanent protection as legal reserves in properties that no longer deforest. Legislation on areas of permanent protection also underwent significant changes in the new code. The adoption of new rules for the allocation of such areas generally reduced the total area under permanent protection inside private properties.

Soares-Filho (2012) estimates that, although the revision of the code reduced Brazil's environmental liability by nearly 60%, over 20 million hectares are still required to be restored to forest.[7] This environmental liability is largely concentrated along the border of the Amazon Forest (8 million hectares), throughout all of the Atlantic Forest (6 million hectares), and in the southern part of the Cerrado (5 million hectares). The author stresses that if, on one hand, the new Forest Code led to a sharp reduction in environmental liability, on the other hand, it enhanced the mechanisms for environmental recovery. He specifically highlights the development of the Environmental Reserve Quota (*Cota de Reserva Ambiental*, CRA), a title that allows areas of environmental surplus in one property to compensate those of environmental deficit in another.

In short, the new Forest Code reduced the cost of complying with environmental regulation for rural landowners (TNC, 2013). It allowed agricultural producers to continue operating within their properties under greater legal stability, and enabled them to collect benefits and revenues associated with certification and environmental services. Moreover, Soares-Filho (2012) claims that the enforcement of the new Forest Code would not jeopardize Brazil's agricultural development. He argues that there is only a small conflict between areas that must be recovered and those that are being used for crop farming. Improved cattle ranching productivity could sustain current levels of beef production in smaller areas of pasture, and thus make more land available for transitioning into crop farming. In spite of all this, implementing and enforcing the new Forest Code remains a large political and operational challenge.

[6] Hargrave and Kis-Katos (2013) also find that increased law enforcement reduced Amazon deforestation rates.

[7] The term "environmental liability" refers to the total area that must be restored or recovered within Brazilian territory to meet minimum legal requirements regarding forest cover. In contrast, the term "environmental asset" refers to the total area that exceeds these requirements.

3.3 Challenges and Opportunities

Pressing questions about the protection of Brazil's natural resources are still unanswered. Addressing these questions within a P&P framework that looks at key socioeconomic aspects affecting the forestry sector provides an opportunity to better tailor Brazilian environmental policy, and steer it towards more efficient and sustainable use of the country's forests. This section looks at some of the challenges and opportunities for protection in Brazil, focusing on institutions, technology, financing, risk, and infrastructure.

Institutions

The institutional framework for the protection of natural resources in Brazil's public lands and the instruments for applying this framework are more consolidated than those for private protection. Public protection is already at a stage that enables testing the effectiveness of its main instruments. There is typically very limited deforestation occurring inside Amazon protected areas, but a substantial amount concentrated in their immediate surroundings. In light of this, **a better understanding about the net impact of protected areas, which accounts for deforestation patterns both inside and around protected areas, is needed to help design conservation policy**.

Private protection, in turn, is at a much earlier stage of implementation than public protection. **The Forest Code, which determines the regulatory framework for private protection, has recently been revised, and an instrument for enforcing this framework has been developed. Today, the challenge lies in effectively using this instrument to implement the Forest Code, as well as in clarifying property rights, without which the code's implementation will be very challenging.**

Public protection: protected territory

Publicly protected areas in Brazil can take one of three forms: (i) strictly protected conservation units, where ecosystems are to be kept free of human interference and only the indirect use of the area's natural attributes is legally permitted; (ii) conservation units of sustainable use, in which sustainable exploitation of a fraction of the area's natural resources is allowed under conditions established in the area's technical management plan; or (iii) indigenous lands, whose occupation is restricted to native populations, and where both the clearing and the use of natural resources are legally permitted for traditional activities only. Of Brazil's total land area, 13% is currently occupied by indigenous lands, 10% by conservation units of sustainable use, and 5% by strictly protected conservation units.

Between 2002 and 2011, protection extended over an additional 66 million hectares of the Amazon biome (see Figure 3.4a). Most of this expansion occurred through the creation of strictly protected conservation units, whose total area nearly doubled during this period, and conservation units of sustainable use, whose area more than doubled in the same ten years. Under the PPCDAm framework, the locations of newly-created protected areas were strategically chosen to obstruct the advancement of forest clearings moving in from the Arc of Deforestation. Figure 3.5 clearly illustrates this, depicting the spread of protected territory mostly along the central and northern-most regions of the Amazon biome.

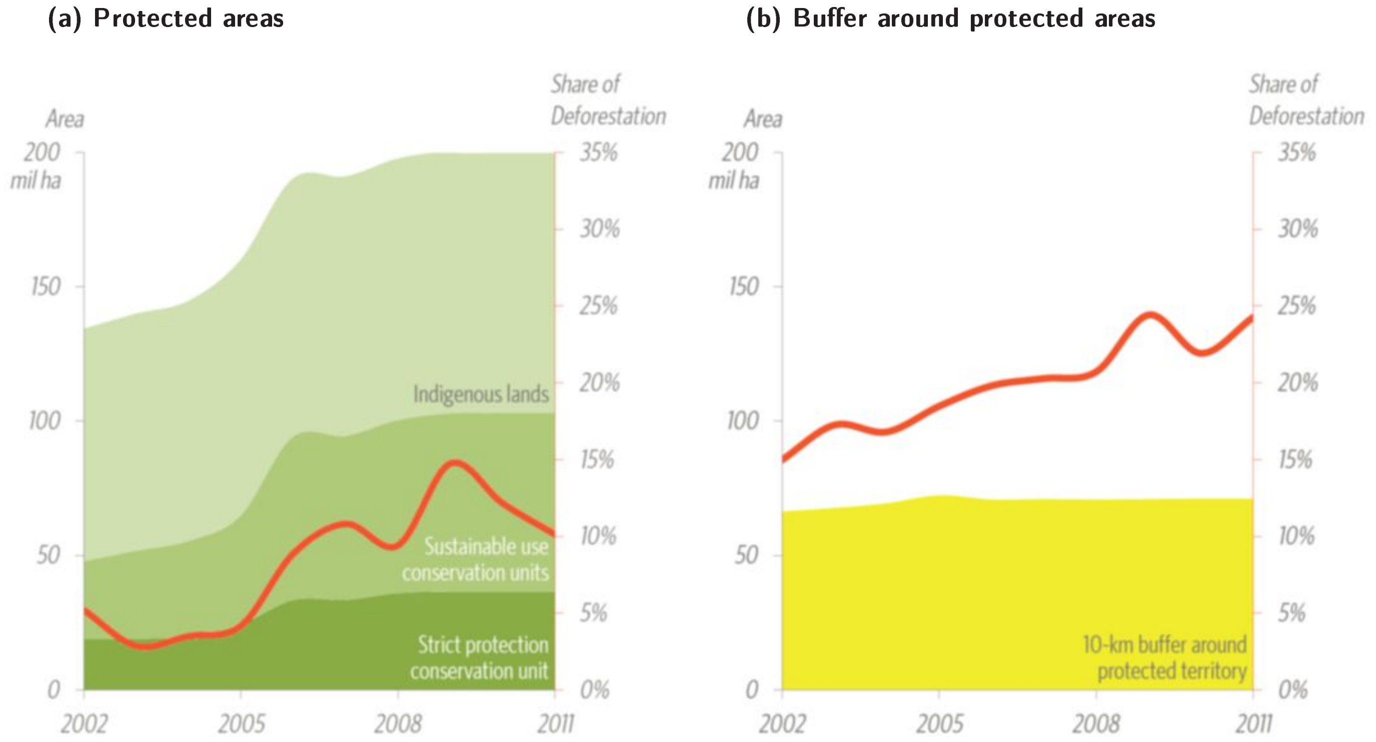
The patterns shown in Figure 3.5 suggest **there is very limited clearing of native vegetation occurring inside protected areas, but substantial deforestation in their immediate surroundings.** Indeed, clearings within protected territory account for a relatively small share of total annual Amazon deforestation – on average, less than 10% (see Figure 3.4a).[8] In contrast, from 2002 through 2011, the share of total annual Amazon deforestation occurring within 10 kilometers of protected areas rose from 15% to 24% (see Figure 3.4b). This increase is even more striking considering that the total area of the 10-kilometer buffer around protected territory practically did not increase during this period.[9]

What is the net impact of protection? The key to answering this question is to consider not only the direct impact of protection, but also potential spillover effects. Understanding this net impact and accounting for it in conservation policy design can help build a more effective environmental protection strategy.

[8] Forest clearings occurring in indigenous lands and conservation units of sustainable use may be legal.

[9] Figure 3.4 indicates there is little variation in total buffer area over time, despite the increase in total protected territory. This is due to the fact that many protected areas in the Amazon are created either very close or right next to one another. Because protected territory itself is not included in the buffer, the creation of a new protected area close to existing protected areas will certainly add to total protected territory, but won't necessarily increase total buffer size.

Figure 3.4 Amazon Protected Teritory: Size and Share of Annual Deforestation, 2002–2011



Notes: Panel (a) shows the total area of protected territory (by category of protection) and the share of total annual Amazon deforestation occurring inside it; Panel (b) shows the total area of a 10-kilometer buffer around protected territory and the share of total annual Amazon deforestation occurring inside it. The sample is composed of the Amazon biome. Data sources: FUNAI (2013), INPE (2013), and MMA (2013).

In particular, assessing how different types of protection affect forest clearing patterns inside and around protected territory can enhance knowledge about the effects of conservation units of sustainable use, and thus contribute to the development of a sustainable forestry sector.

Private protection: environmental and land regularization

Addressing the issue of environmental and land regularization in Brazil is central to the implementation of a P&P strategy for efficient land use.[10] Given Brazil's institutional setup, law enforcers have greater capacity to punish illegal deforestation when they catch offenders red-handed. Although Brazilian environmental legislation allows for punishment of past deforestation, once an area has been cleared, it becomes a small part of the enormous contingent of illegally cleared land in Brazil. Effective punishment of illegal deforestation in such areas, where land and production property rights are often unclear, is far less feasible.

The adoption of DETER-based monitoring and targeting of law enforcement significantly increased law enforcers' capacity to quickly reach forest clearings, thereby also increasing their ability to punish illegal deforestation. However, the Amazon's history of irregular colonization contributed to a current scenario in which land disputes, illegal occupations, and illegitimate titling abound.[11] Enforcing environmental regulation within private property is virtually impossible when property rights are not well established. **Environmental and land regularization, with a particular focus on the establishment of property rights, should therefore be major themes within conservation policy.**

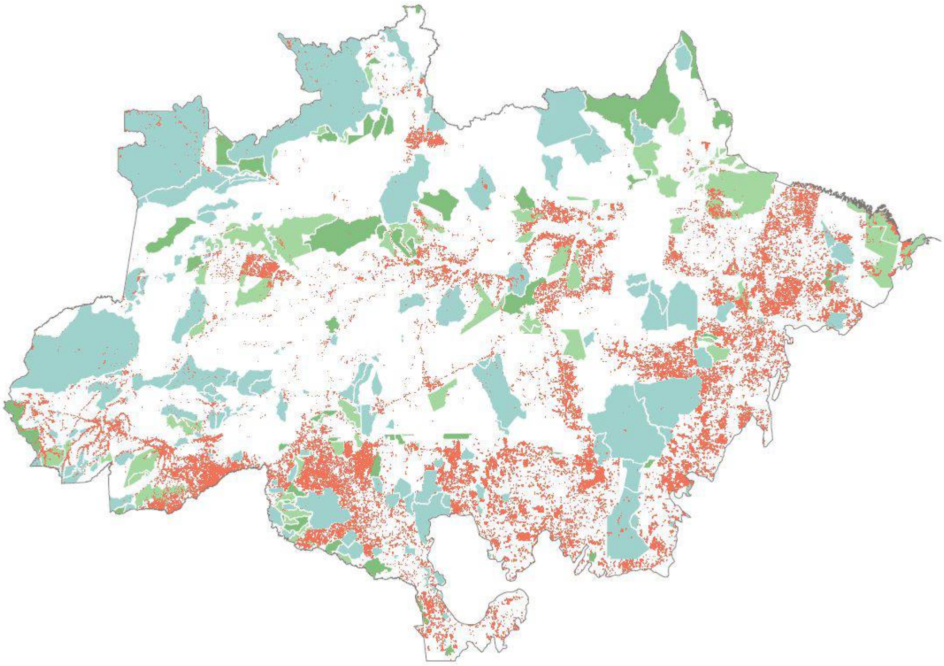
The approval of the new Brazilian Forest Code reinforced the need for both environmental and land regularization. To prove compliance with the code's regulations, particularly those concerning legal reserves and areas of permanent protection, landowners must

[10] Environmental regularization refers to changes landowners must implement to ensure compliance with environmental regulations. Land regularization refers to changes landowners must implement to ensure compliance with land titling regulations.

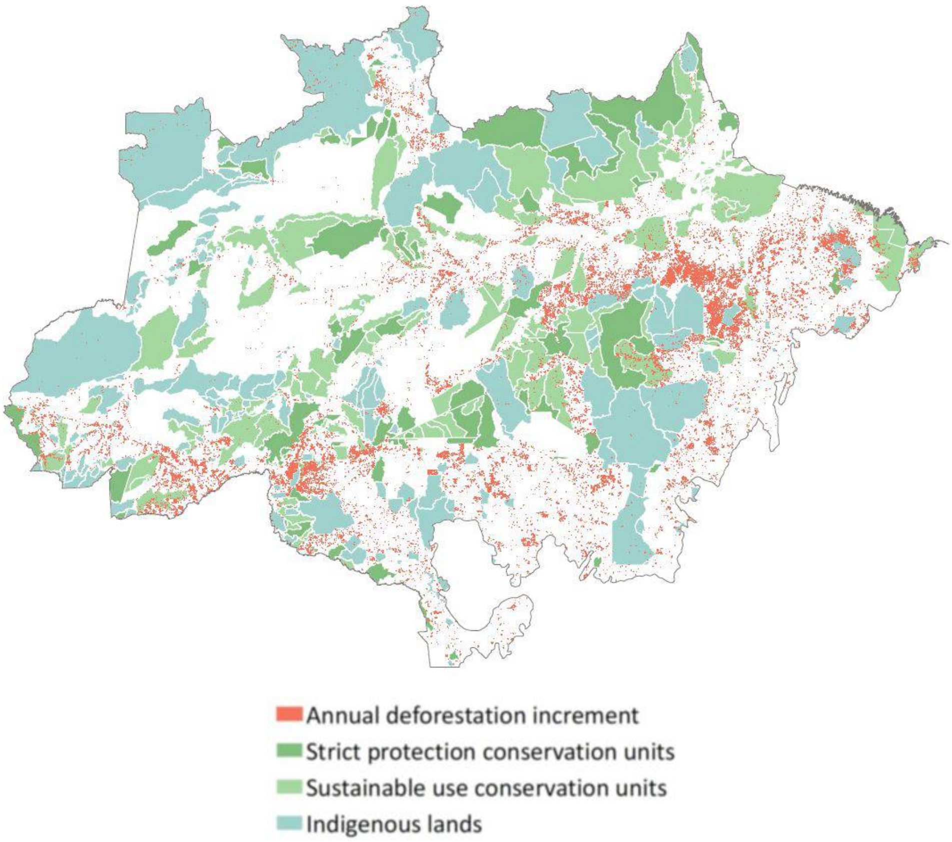
[11] See Section 3.3 for a more detailed account of this colonization.

Figure 3.5 Amazon Protected Territory and Deforestation

(a) 2002



(b) 2011



Notes: The map shows the location of protected areas and annual deforestation increments in the Amazon biome. Protected areas are divided into strictly protected conservation units, conservation units of sustainable use, and indigenous lands. Data sources: FUNAI (2013), INPE (2013), and MMA (2013).

obtain certification that their properties abide by environmental standards. Yet, the enforcement of environmental regulation for certification requires well-established rural property rights, which hinges on advancing land regularization.

CAR

The Environmental Rural Registry (CAR) was established in the late 2000s to integrate environmental information concerning areas covered by native vegetation within private rural properties.[12] The CAR requires that all such properties undergo a georeferencing procedure to record geographical coordinates not only for property limits, but also for the location of key geographic features, legal reserves, and areas of permanent protection within these limits. Crossing this information with available detailed satellite data on forest clearings not only contributes to promote stricter environmental law enforcement, but also helps characterize patterns of forest clearing within private properties.

The CAR's contribution to a P&P strategy is twofold:

- **From a protection standpoint, the CAR stands as the main instrument for enforcing the Forest Code and improving the design of Brazilian rural landscapes.** It allows private landowners to calculate how much land must be protected within their property under the new Forest Code. In some cases, this implies recovering native vegetation, which is a costly procedure that requires careful planning to efficiently allocate legal reserves and areas of permanent protection. The CAR provides property-level land cover details that enable such planning. Moreover, it contains valuable information that facilitates the coordination of conservation efforts at a more aggregated level. Consider, for example, contiguous landholdings that belong to different owners. By combining information from each property's CAR, individual legal reserves can be shaped and allocated such that, together, they deliver greater environmental value. This can help achieve important environmental goals, such as the protection of ecological corridors.
- **From a production standpoint, the CAR contributes to the establishment of property rights and supports the planning of efficient land use.** It provides the Brazilian Ministry of Agriculture and state environmental secretariats with informational input for ecological-economic zoning and territorial management efforts, and thereby improves the targeting of such policy action.

In light of this, it is encouraging to see that the uptake of CAR has been significant – in 2011, over 20% of the territories of both Mato Grosso and Pará states were occupied by private properties registered in the CAR system (SEMA MT, 2013; SEMA PA, 2013).[13] **Although the CAR currently stands as the key instrument for promoting environmental regularization in Brazil, little is actually known about its effect on the preservation of native vegetation.**

INCRA settlements

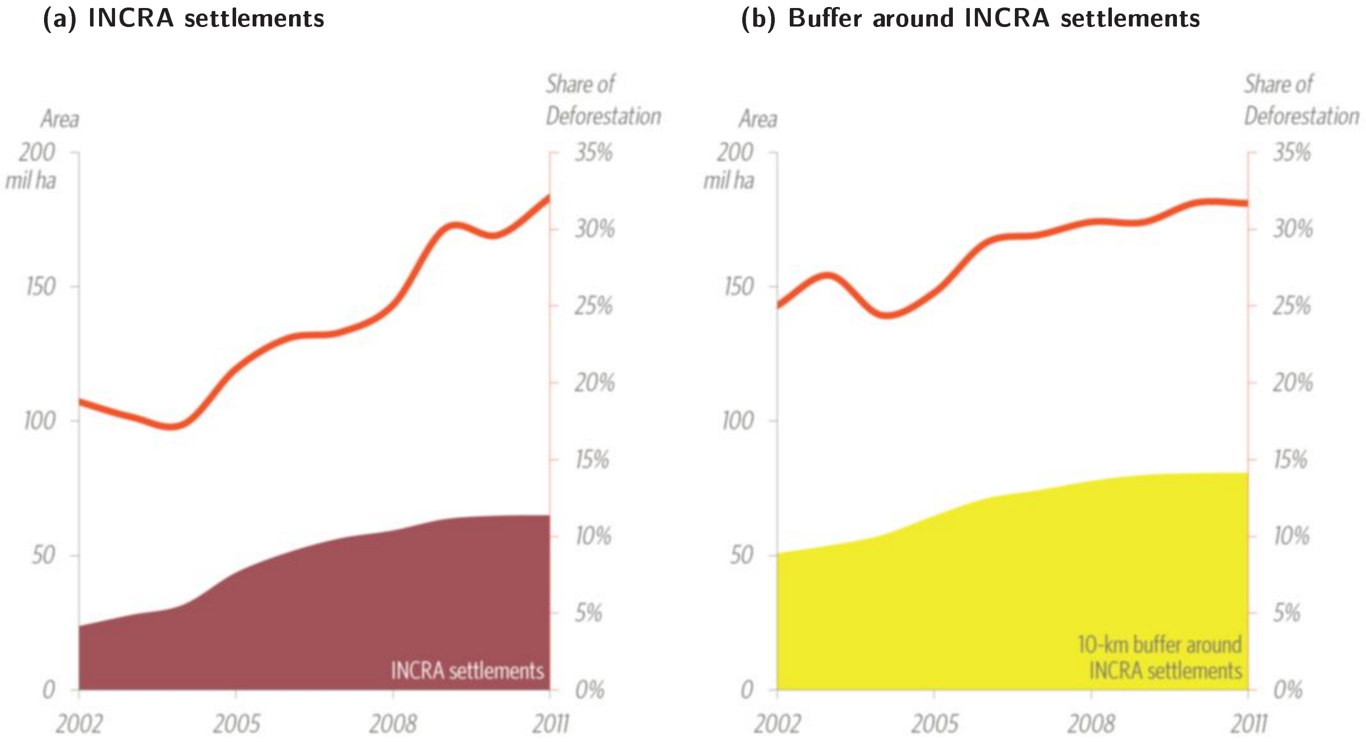
The National Institute for Colonization and Land Reform (INCRA) is an independent federal agency that administers issues concerning land reform and land regularization in Brazil. Its reform-related efforts include setting up rural settlements for underpriviledged agricultural producers lacking property.

There is limited information about the impact of INCRA's recent Amazon land regularization efforts. The area occupied by INCRA settlements in the Amazon biome nearly tripled between 2002 and 2011 (see Figure 3.6). The share of total annual Amazon deforestation happening inside settlements and within 10 kilometers of them also increased during this period – by 2011, about a third of forest clearings were located inside INCRA settlements, and another third in their surroundings. Combined, INCRA settlements and their 10-kilometer buffers occupied about 35% of the Amazon biome in 2011, and accounted for 64% of recorded deforestation in that year. Although causation cannot be established from simple descriptive data, these data show that **a substantial share of recent deforestation tends to concentrate in and around INCRA settlements. Relevant details about this relationship, such as the drivers behind this pattern, the actual direction of causation, and the**

[12] The term CAR is used throughout this report to refer to all environmental regularization systems that require georeferencing of the private property. In the late 2000s, some states implemented such systems under different names. In the early 2010s, federal legislation unified these systems under the CAR.

[13] The states of Mato Grosso and Pará saw intense deforestation activity in the 2000s.

Figure 3.6 Amazon Settlements: Size and Share of Annual Deforestation, 2002–2011



Notes: Panel (a) shows the total area of INCRA settlements and the share of total annual Amazon deforestation occurring inside them; Panel (b) shows the total area of a 10-kilometer buffer around INCRA settlements and the share of total annual Amazon deforestation occurring inside it. The sample is composed of the Amazon biome. Data sources: INCRA (2013) and INPE (2013).

nature of these forest clearings, remain unknown.

Enhanced understanding about environmental and land regularization efforts in the Amazon, particularly concerning the impacts of establishing property rights, can provide critical insight into how to best enforce environmental law at the private property level and thus help integrate production and protection efforts. Moreover, it can contribute to meet the large institutional challenges presented by the implementation of the new Forest Code. Overcoming these challenges is by no means a trivial task. Yet, **an efficient P&P strategy requires solid institutional foundations – establishing these foundations must therefore be a priority for Brazil.**

Technology

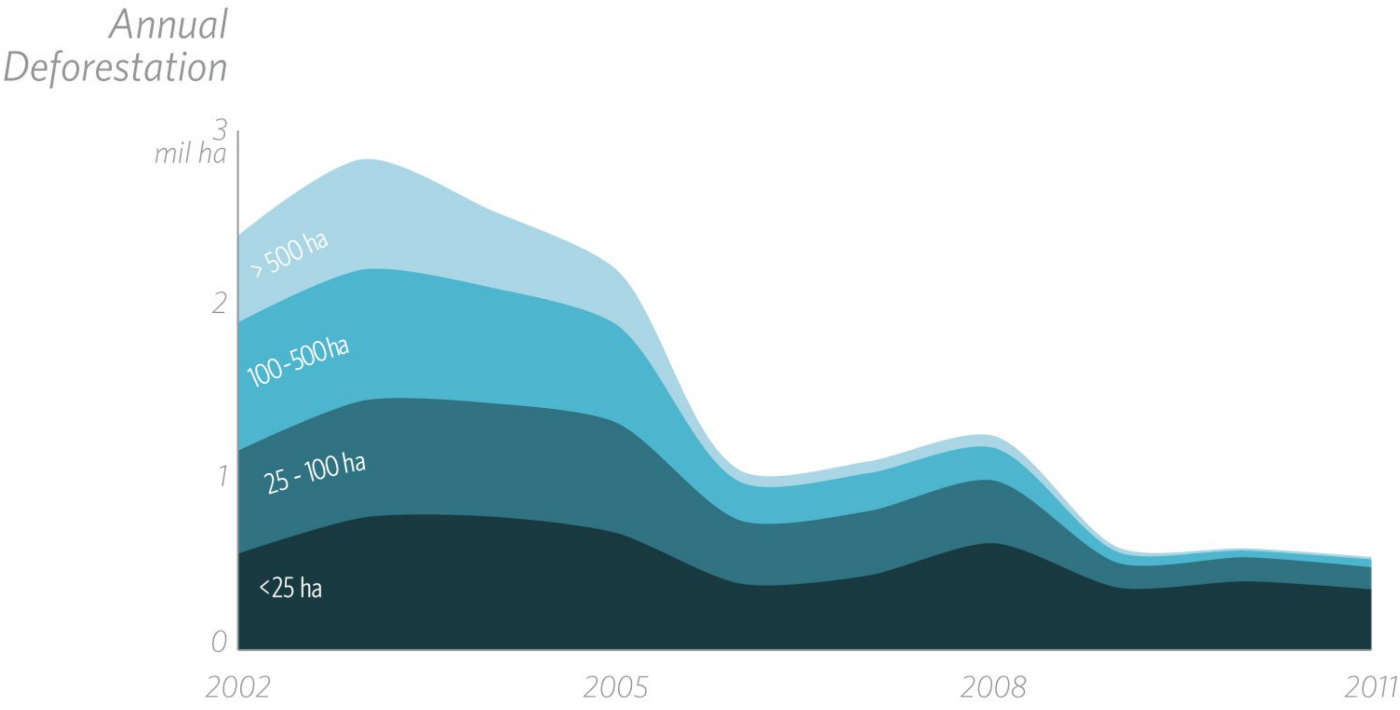
Technology played a crucial role in strengthening Brazil's conservation efforts in the mid-2000s. The implementation of DETER-based monitoring brought substantial improvements to Amazon law enforcement capacity, significantly contributing to curb deforestation in the region (Assunção et al., 2013a). Technological enhancements can contribute to further reduce Amazon deforestation, as well as to extend environmental monitoring and law enforcement over Brazil's other ecosystems.

Improve remote sensing-based monitoring

DETER is unable to detect land cover patterns beneath clouds. The system captures forest clearing activity by comparing later satellite images for any given location in the Brazilian Amazon with earlier images for that same location. When this comparison detects changes in forest cover, the system issues a deforestation alert that pinpoints the exact location of the forest clearing. However, the satellite used in DETER is incapable of detecting land cover patterns in areas covered by clouds – no deforestation activity is identified in these areas and, thus, no alerts are issued. Law enforcers are therefore less likely to target these areas.[14]

[14] Assunção et al. (2013a) show that the intensity of law enforcement is systematically lower in Amazon municipalities with greater average annual cloud coverage. This result indicates that DETER's inability to detect land cover patterns beneath clouds

Figure 3.7 Amazon Deforestation: Forest Clearings by Polygon Size, 2002–2011



Notes: The figure shows total annual Amazon deforestation decomposed into four categories of deforestation polygon size. A deforestation polygon is a contiguous deforested area, as captured in satellite imagery. The sample is composed of the Amazon biome. Data source: INPE (2013).

Overcoming DETER's incapacity to detect land cover patterns beneath clouds could thus improve law enforcement targeting capability and add significant value to Brazil's conservation efforts. Amazon monitoring will soon be enhanced through the use of Japanese radar technology, capable of detecting land cover patterns beneath cloud coverage. This effort, and others like it, help Brazil achieve more effective environmental protection.

Improve satellite resolution to combat small-scale deforestation

The satellite used in DETER is only capable of detecting forest clearings whose total contiguous area is greater than 25 hectares. Any clearings smaller than this minimum visibility threshold are not captured by DETER and, thus, do not trigger deforestation alerts. They are therefore less likely to be caught by law enforcers. However, the satellite used in Brazil's Project for Satellite Monitoring of Legal Amazon Deforestation (*Projeto de Monitoramento do Desmatamento na Amazônia Legal por Satélite*, PRODES), used to estimate annual Amazon deforestation increments, has a minimum visibility threshold of 6 hectares. Forest clearings whose total contiguous area is larger than 6 hectares but smaller than 25 hectares will therefore be detected by PRODES and accounted for in annual deforestation data, but will not be detected by DETER.

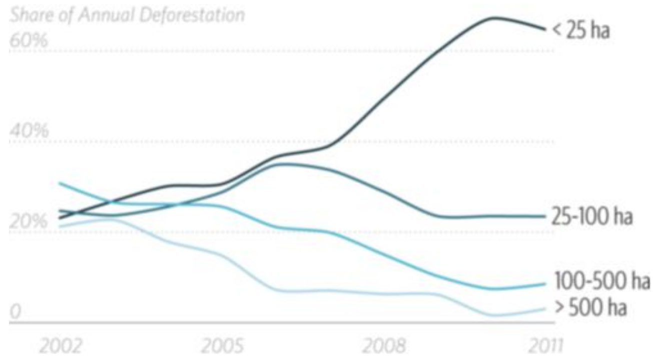
Recent Amazon deforestation trends suggest that the dynamics of Amazon forest clearings may be changing in response to this. **In the early 2000s, Amazon deforestation resulted mainly from the clearing of large contiguous areas of forest – in PRODES terminology, large deforestation polygons. In recent years, however, deforestation has been driven mostly by the cutting down of forest in small increments** (see Figure 3.7). Indeed, the relative participation in annual deforestation of polygons smaller than 25 hectares – precisely those that are not detected by DETER – rose sharply in the second half of the 2000s (see Figure 3.8). In 2002, such polygons accounted for less than a quarter of total annual deforestation; by 2011, this fraction had increased to about two thirds.

This pattern of decreasing average deforestation polygon size may be a symptom of DETER's technological

does, in fact, influence the targeting of law enforcement in the Amazon.

shortcoming. After all, the system's effectiveness is limited by its ability to detect changes in land cover. The predominance of comparatively small deforestation polygons driving recent deforestation might therefore represent forest clearing activity that currently eludes Brazil's Amazon monitoring capacity. This recent change in deforestation dynamics presents new challenges for further reducing Amazon forest clearings. **Did those who clear forests in large increments adapt their behavior to the system's known limitations, or did the profile of deforesters actually change? The answer to this question is crucial to target future efforts to combat deforestation.** A better characterization of the nature of current Amazon deforestation practices could inform future conservation policy, as well as contribute to the identification of new opportunities for technological improvements.

Figure 3.8 Amazon Deforestation: Relative Participation by Polygon Size, 2002–2011



Notes: The figure shows the relative participation of each polygon size category in total annual Amazon deforestation. A deforestation polygon is a contiguous deforested area, as captured in satellite imagery. The sample is composed of the Amazon biome. Data source: INPE (2013).

Extend environmental monitoring beyond the Amazon

There are additional technological challenges related to the implementation of a countrywide P&P strategy and development of a national sustainable forestry sector. To accomplish these goals, **Brazil needs to extend effective monitoring and law enforcement over biomes beyond the Amazon.** This applies particularly to the Cerrado, given its already large extent of cleared native vegetation and high agricultural attractiveness. The technical challenges it faces in doing so may be sizeable. These include, but are not limited to, developing systems capable of quickly detecting changes in land cover in areas with sparser native vegetation (as compared to tropical rainforests), adapting remote sensing-based systems to deal with natural phenomena inherent to different ecosystems, and maintaining regular and frequent generation of high-quality data at the national scale.

Financing

The resources that finance the protection of the Brazilian forestry sector are typically used either in the direct protection of native vegetation, or in creating incentives for sustainable behavior. **There is great need for analysis regarding the impact and effectiveness of financing for environmental protection.**

Availability and use of resources for environmental protection

Direct protection is largely ensured via monitoring and law enforcement, both within private properties (through the enforcement of the Forest Code) and in public lands (through the enforcement of regulations regarding protected areas). Created by the Brazilian federal government and coordinated by the Ministry of the Environment, the Program for Amazon Protected Areas (*Programa Áreas Protegidas da Amazônia*, ARPA) is a good example of how financing is used in direct protection. ARPA brings together funds from the Global Environment Facility, the German government (via the German Development Bank), the World Wildlife Fund, and the Amazon Fund, under financial management by the Brazilian Biodiversity Fund (*Fundo Brasileiro para a Biodiversidade*, FUNBIO). State and municipal governments, as well as civil society organizations, partner with the Ministry of the Environment and the Brazilian environmental police in the implementation of ARPA. Launched in 2002 to last through 2015, the program was created to expand and strengthen Amazon conservation units. Funds from ARPA are used to support the development of management plans and councils, territorial surveys, and monitoring activities in conservation units. With a commitment from its partners to invest USD 400 million over 10 years, ARPA is regarded as one of the largest programs for conservation of tropical forests in the world.

Incentive-based efforts are somewhat more diverse in terms of operation and financing. Resources to finance the promotion of sustainable forestry practices are currently available via numerous funds and programs, the two most prominent examples being the Amazon Fund and the National Climate Change Fund (also known as the Climate Fund). Created in 2008, the Amazon Fund provides resources to be used in non-reimbursable investments for monitoring and combating deforestation, as well as for promoting sustainable use and preservation of forests in the Amazon Biome. Funds originate from donations, most of which have been made by the Norwegian government. To date, the Amazon Fund has received USD 612 million. The Climate Fund, in its turn, was instituted in 2010, with the purpose of acting as an instrument for the promotion and financing of activities intrinsic to national policy on climate change. Resources can be used to finance projects aimed at mitigating the negative effects of climate change, as well as to support research relevant to Brazilian climate change policy. Both reimbursable and non-reimbursable projects can be financed using the fund's resources. The Climate Fund collects donations, but also receives up to 60% of the resources originating from the production of petroleum in Brazil. It currently holds USD 264 million, and is due to receive additional resources at an annual basis.

Despite the relatively large availability of resources, these funds appear to experience difficulties in using a significant share of their resources. Indeed, contrary to what most might expect, **the greatest challenge concerning the financing of a sustainable forestry sector in Brazil is not acquiring resources, but rather using them efficiently**. The Amazon Fund, for example, had only disbursed USD 87 million by the second half of 2013 – less than a fifth of the available resources.

Why is this the case? Answering this question – and, more importantly, reverting this scenario – starts with an effort to better understand the financial environment within which these resources are to be used. Assunção et al. (2013b) take a step in this direction, using an empirical exercise to explore the relationship between the availability of rural credit and forest clearings. The authors find a positive relationship between the concession of rural credit in the Amazon biome and deforestation, which they interpret as evidence of credit constraints in the region.[15] Their results further suggest that the relationship between rural credit and deforestation varies across local economic settings – rural credit has a stronger impact on deforestation in places where cattle ranching (as opposed to crop farming) is the leading economic activity. In light of these varied effects, **an in-depth characterization of the economic environments for different representative areas of Brazil could help tailor policy to better fit the needs of each specific area**.

These results have important implications for policy design, specifically for policy regarding financing of activities in sustainable forestry. They suggest that **policies that increase the availability of financial resources could lead to higher deforestation, depending on the economic setting within which the resources are used. This does not imply that such policies will necessarily increase forest clearings, but that policy design should account for the nature of financial constraints prevailing in its target region to avoid potentially adverse rebound effects.**

The role of payment for environmental services

Understanding the nature of local financial constraints is particularly relevant for policies that entail payment for environmental services (PES), in which monetary incentives are offered to producers who manage their land to deliver some sort of environmental service. **PES is expected to play a significant part in the implementation of a countrywide P&P strategy. This is largely due to the fact that monitoring and law enforcement are only expected to be effective at curbing illegal deforestation.** Currently, most of the deforestation that occurs in the Brazilian Amazon is still illegal – either because private landholders do not comply with environmental regulations regarding legal reserves and areas of permanent protection, or because forest clearings occur in public land.[16] However, a large share of forest clearings occurring outside the Amazon biome might actually be legal, since the Forest Code determines less stringent requirements regarding legal reserves in non-Amazon biomes (see Section 3.2 for details). In light of this, incentive-based policies (including PES) will likely be needed to promote the preservation of native vegetation beyond what is legally

[15] Based on Banerjee and Duflo (2012), Assunção et al. (2013b) argue that the reduction in the concession of subsidized rural credit induced by Resolution 3,545 may have tightened credit constraints, leading to changes in farmers' production decisions, and thereby affecting deforestation.

[16] Forest clearing activity is only permitted by law within private properties and according to regulations established in the Forest Code. All deforestation occurring in public land is therefore illegal, except when otherwise determined by the appropriate legal instruments (such as forest clearing for the practice of traditional activities by indigenous peoples inside recognized indigenous territory).

required of private landholders in non-Amazon biomes.

The Cerrado is a particularly relevant case. Brazil's second largest biome has seen over 100 million hectares of deforestation, with the latest estimates indicating that about half of the Cerrado remains covered by native vegetation (IBGE, 2013c). Compared to properties in the Amazon, the Forest Code determines that landowners in the Cerrado hold a smaller share of their landholding as legal reserves. Monitoring and law enforcement alone are therefore unlikely to deter a significant amount of deforestation in the Cerrado, highlighting the need for incentive-based policies to combat the clearing of the biome's native vegetation.[17]

Developing and implementing effective PES policies and programs is a challenging task. Recent empirical work has yielded relevant implications for the design of such policies and programs.[18] First, because agricultural commodity prices are shown to be relevant determinants of Amazon deforestation, the shadow price of preserving the forest is expected to change with changing agricultural prices. **Commodity price variations should therefore be incorporated into PES compensation schemes to ensure farmers have sufficient incentive to preserve forestland.** Second, the positive empirical relationship between rural credit and Amazon deforestation, alongside empirical evidence of credit constraints in the region, suggest that increased availability of financial resources could lead to greater deforestation. **PES policy design should thus consider the nature of regional financial constraints and strictly enforce conditionality to avoid potentially adverse rebound effects.** Third, the impact of PES policies could be enhanced through more stringent environmental monitoring and law enforcement. **In addition to curbing illegal deforestation, the large deterrent effect of monitoring and law enforcement efforts may also help enforce compliance with PES conditions.**

[17] It's worth noting that a share of forest clearings in Cerrado private properties may be illegal even if they respect the Forest Code's requirements for legal reserves. The code also determines that deforestation in private properties is only allowed when the landowner has a license to deforest. Since acquiring such license may be a time-consuming and costly process, several Cerrado-based landownders likely do not have it. The clearing of native vegetation in private properties without a license is illegal regardless of the clearing's extent. Monitoring and law enforcement are expected to have a significant deterrent effect on this type of illegal activity.

[18] Among others, see Assunção et al. (2012), Assunção et al. (2013a), Assunção et al. (2013b), and Hargrave and Kis-Katos (2013).

Risk

Political risk is one of the main sources of uncertainty regarding the protection of natural resources in Brazil. Government action for protection, be it on public or private land, is necessary for conservation. Yet, it is also politically risky, particularly in light of the supposed trade-off between production and protection. The P&P strategy partially mitigates this political risk, to the extent that it simultaneously promotes the seemingly antagonistic goals of economic growth and protection of natural resources. **Through enhanced understanding of local economic dynamics and the identification of potential efficiency gains, the P&P strategy informs public policy and enables the realization of both production and environmental gain, thereby reducing the political risk associated with the conservation of native vegetation.**

In addition, sustainable forestry is just emerging in Brazil, and, as with most budding efforts and businesses, it bears substantial risk. From the perspective of a private entrepreneur, there are many open questions to be answered and operational details to be determined before a solid business plan can be defined for the sector. **The lack of secure property rights – both physical and intellectual property rights, it is important to stress – imposes a cost on developing sustainable forestry practices.**[19] Consider the problem of squatters in the Amazon as an illustration of how burdensome it may be for private entrepreneurs to set up a sustainable forestry business in the forest – neither the property of land nor of its products can be ensured under frail property rights, thereby limiting entrepreneurs' capacity to reap the rewards of their risky investments. Uncertainties regarding the enforcement of environmental law, particularly that of the new Forest Code, further compromise entrepreneurs' efforts, increasing their perception of risk and insecurity. **In a scenario of considerable institutional risk, delivering environmental services has known high costs, and, at least for the time being, relatively less tangible benefits.**

[19] For more on properties rights, see Mendelsohn (1994), Angelsen (1999), Alston and Mueller (2010), and Alston et al. (2012), among others.

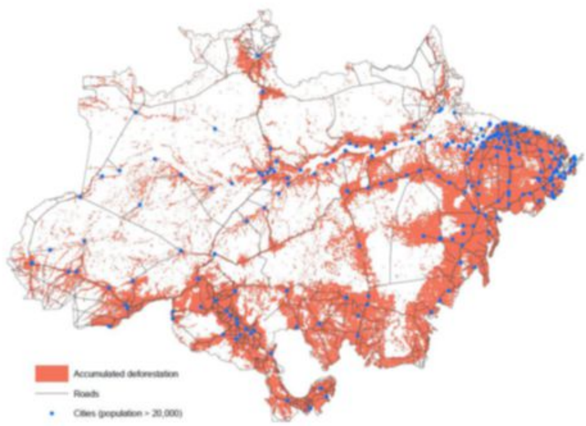
Infrastructure

The spread of infrastructure – particularly that of roads – has long been associated with deforestation.[20] Figure 3.9 appears to reinforce this. **The map shows that forest clearings in the Amazon biome tend to concentrate in and around areas served by roads, which are also, not coincidentally, the areas hosting the biome's largest cities.** In fact, the correlation appears strongest precisely close to cities, likely a sign that forest clearings are largely driven by the proximity to consumption markets (and not necessarily by roads themselves). Although impressive, this graphical evidence is not conclusive. The clear visual correlation must be interpreted in light of the Amazon's history of occupation. The construction of major roadways in the region began in the 1960s, at a time when the Brazilian government advocated Amazon immigration as a means of integrating national territory. In addition to bringing infrastructure to the Amazon, the government conditioned the concession of credit upon proof that the potential borrower had cleared some minimum amount of forest – land, not forest, was the critical asset. The preservation of natural resources was not a primary concern then, with public policy focusing on bringing economic development to the region by promoting local production.

While the advent of basic infrastructure brought by the flow of occupants may have indirectly contributed to deforestation by facilitating penetration into the forest and helping consolidate local urbanization, infrastructure cannot be said to be intrinsically deleterious to native vegetation. The relationship between infrastructure and deforestation is, in fact, ambiguous. On the one hand, there is empirical evidence (including Amazon-based) attesting to the positive correlation between the two.[21] On the other hand, there is also evidence that the demand for the preservation of natural resources increases with increasing levels of national income,[22] and high income is typically associated with more infrastructure. Additionally, infrastructure appears to be correlated with higher productivity in Brazilian agricultural production (see Section 2.3), which should allow producers to expand production without expanding into forestland.

Combined, these results suggest that **it is not infrastructure itself that causes deforestation, but rather the development of infrastructure that is not accompanied by adequate environmental monitoring and law enforcement.** The case of the Brazilian Amazon fits this description. The government encouraged the occupation of the forest, but did not promote the establishment of basic local institutions, such as property rights. During the occupation, environmental laws were not enforced – in fact, many were not even created until many years later. More recently, despite substantial improvements in monitoring and law enforcement capacity, the Amazon's fragile property rights system still stands as an obstacle to the enforcement of law. The relationship observed between infrastructure and deforestation in the Brazilian Amazon is therefore historical, not necessarily intrinsic.

Figure 3.9 Amazon Accumulated Deforestation, Road Network, and Cities



Notes: The map shows accumulated deforestation through 2011, main roads, and cities with a population of at least 20,000 inhabitants in the Amazon biome. Data sources: DNIT (2013), IBGE (2013b), and INPE (2013).

Infrastructure can actually be intrinsically good for the promotion of an efficient P&P strategy, as long as it is implemented alongside solid law enforcement. **Improvements in infrastructure can help boost agricultural productivity, thereby reducing the demand for land under effective enforcement, and thus alleviating deforestation pressures. Better infrastructure coupled with better enforcement have enormous potential to contribute to the shift into sustainable high-productivity agricultural production.** Combining productivity-boosting

[20] Among others, see: Panayotou and Sungsuwan (1994); Chomitz and Gray (1996); Cropper et al. (1997); Angelsen and Kaimowitz (1999).

[21] Among others, see: Reis and Margulis (1991); Reis and Guzmán (1994); Andersen (1996); Pfaff (1999).

[22] See Antle and Heidebrink (1995) and Foster and Rosenzweig (2003).

infrastructure with effective environmental law enforcement remains a pressing challenge Brazil is yet to meet.

3.4 Key Policy Implications

There is ample scope for policy action in addressing the challenges discussed in this chapter. Many of these challenges are, in fact, opportunities for enhancing the protection of Brazil's natural resources.

To seize these opportunities, Brazil must focus on some key policy efforts. First, improve the enforcement of environmental regulation within private landholdings, particularly through the advancement of the CAR. Second, overcome technological shortcomings that limit the country's capacity to combat small-scale Amazon deforestation. Third, promote effective environmental monitoring and law enforcement in all of its ecosystems, accounting for the intrinsic differences across biomes. Fourth, develop a sustainable forestry sector and market-based incentives for the protection of natural resources.

Furthermore, Brazil must seek answers to the many open questions regarding environmental protection within its national borders. A better understanding of the effects of important conservation efforts and economic decisions – and, in particular, one that accounts for Brazil's enormous diversity across ecosystems and economic settings – is crucial to the tailoring of more effective environmental policy. Analytical efforts pursued within a P&P framework can deliver such understanding, and thereby contribute to the design of public policy.

Part III

Production

Chapter 4

Large-Scale Cattle Ranching

Chapter Preview

Cattle ranching is the most land-intensive activity in Brazil: in 2006, pastures covered 160 million hectares, or nearly half of the country's farmland. It is also an activity frequently associated with deforestation. Take the emissions from the beef production process into account and it is clear that cattle ranching significantly impacts GHG emissions. This is why it is a key focus of the P&P strategy.

Brazil experienced significant conversion of land into and out of pastures between 1970 and 2006; overall, pasture area decreased. During the same period, **cattle ranching productivity doubled**. Productivity improvements, in turn, promoted land conversion as each region became more specialized in the activity where it had a comparative advantage: **in the South and Southeast, pastures gave way to more productive crops**. In the North, cattle ranching was relatively a more productive activity and gained terrain. Yet, cattle farm productivity displays wide variations across and, more surprisingly, within regions of Brazil. Hence, **many farms perform far less efficiently than the best-performing ones do, suggesting that there are opportunities for productivity gains** given the current state of technology.

This chapter argues that policy can have significant impacts on cattle ranching and should be guided by two closely related goals. The first key area for policy is to bring less productive farms closer to the efficient performance of more productive ones, by addressing key drivers of productivity growth, which range from lime and rotational grazing, to better functioning land rental markets. Secondly, policy should tackle the tension between production and protection in the North. Specifically, policy must increase the costs of clearing native vegetation to counter the deforestation pressures arising from increased agricultural productivity.

The chapter starts by presenting some key facts about the evolution and current state of cattle ranching in Section 4.1. It then explores variations in productivity and pastureland conversion in Section 4.2. Section 4.3 analyzes the institutional and technological drivers of farm productivity and land conversions while Sections 4.4 and 4.5 turn to the financing and infrastructure drivers, respectively. Finally, Section 4.6 outlines key policy implications.

4.1 An Overview of Cattle Ranching in Brazil

This section presents some key facts about cattle ranching in Brazil. It first analyzes the evolution of productivity and pastureland from 1970 to 2006, the most recent year for which comprehensive and reliable data is available.

Brazil experienced significant land conversion both into and out of pastures between 1970 and 2006, during which time cattle ranching productivity doubled. Such **productivity gains were associated with decreases in the share of pastureland** on total farmland, except for the North region, where both its productivity and share of pastureland increased. In fact, **cattle ranching in the North illustrates the tension between production and protection, because any expansion of agriculture activities in the region represents a reduction in the Amazon's native vegetation**.

We then present a more in-depth snapshot of cattle ranching in 2006. We show that the country's herd is highly concentrated in relatively few farms: **less than 20% of the cattle farms hold more than 80% of the herd**. The Center-West is particularly remarkable: half of the cattle farms in the region – or 4.3% of the country's cattle farms – account for nearly one-third of country's herd. In addition, despite the productivity gains in the past decades, **cattle ranching largely remains land-intensive, as farms use very little confinement**.

Evolution of Cattle Ranching: 1970–2006

In 1970, pastures in Brazil covered 154 million hectares, or 52% of the country's farmland. After peaking at 179 million hectares in 1985, this figure was at 160 million hectares, or 48% of the farmland, in 2006. During this period, cattle farm productivity increased from 0.5 heads per hectare (HPH) of pasture, to 1.1 HPH.[1]

Figure 4.1 gives more details on the evolution of cattle ranching in Brazil from 1970 to 2006. Panel (a) shows the evolution of productivity and total pasture area, by region. A few patterns emerge from this figure. First, **most of the pasture area in the country has been in the Center-West, which currently accounts for nearly 30% of the country's pastureland**. It is interesting to note that starting in 1996, the Center-West seems to have joined the South and Southeast trend in reducing total pastureland.

Second, **productivity grew steadily throughout this period in all regions**. The North's productivity trajectory in the 20 years from 1985 to 2006 is particularly remarkable: while in the rest of the country productivity grew 43%, from 0.75 to 1.08 HPH, the North's productivity grew 182%, from 0.43 to 1.21 HPH. Throughout 1970 to 2006, the South was the most productive region, followed by the Southeast; in 2006, the gap between the North and the Southeast is barely noticeable.

Third, **the Northeast is the least dynamic region in both dimensions depicted in the graph**. The region's productivity is stagnant: it was at the country's average in 1970, at 0.5 HPH, to become the least productive region in 2006, at 0.84 HPH. And pastureland in 2006 was at the same levels as 1975.

Panel (b) of Figure 4.1 presents the share of pasture in total farmland[2] in the region, instead of the total pasture area. It shows how remarkably different the five regions were in 1970, and how both productivity and share of pastureland have become more similar over time – particularly the Southeast, Center-West, and North regions. The Southeast region saw a reduction in pastures from 58% to 50% of its total farmland during this period.

Despite the *absolute increase* in the Center-West's pastureland between 1970 and 2006 (as seen in Panel a), the *share* of pastures on its total farmland experienced a sharp *decrease* in this period, from 70% to 56%. This implies that total farmland was expanding in the region, and other agricultural activities grew faster than cattle ranching.

In the opposite direction is the North, where pastures accounted for 33% of the farmland in 1985, and 48% in 2006. In some sense, the graph suggests that the North's expansion in pastures is getting close to a limit, as the share of pastures in total farmland becomes close to those of the Southeast and the Center-West.

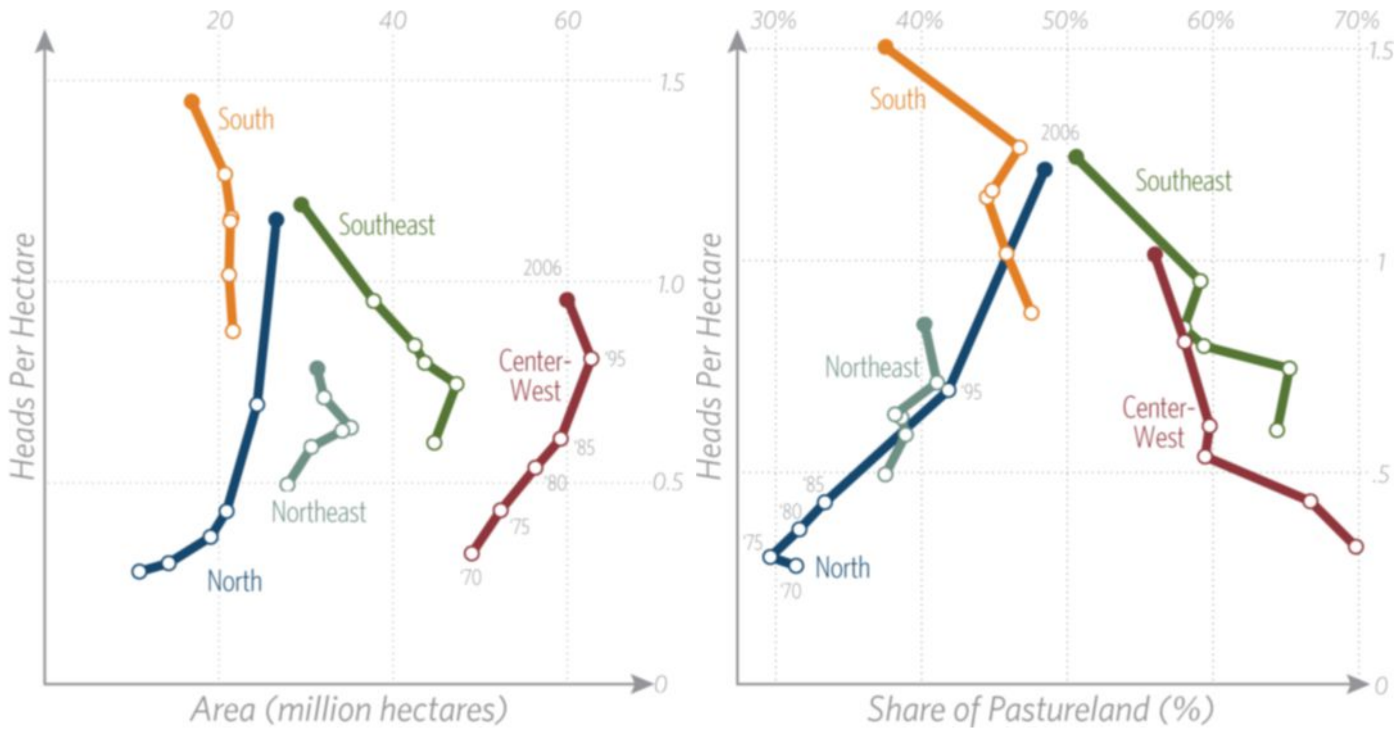
In addition, the fact that 48% of the North's farmland is

[1] Throughout this chapter, we use heads per hectare (HPH) as a measure of cattle farm productivity, where heads are heads of cattle, and hectares are the hectares devoted to pastures. We chose this measure for two reasons. First, large scale cattle ranching is mostly focused on beef cattle, as opposed to dairy cattle. Therefore, other measures such as milk per hectare or milk per cow are less suitable for this chapter's purposes. As chapter 6 will show, this is not the case for small-scale farming. Secondly, there are no comprehensive and reliable data on cattle weight per hectare, which would be a more accurate productivity measure.

[2] Total farmland here means total land within the rural establishments of the country.

Figure 4.1 Cattle Ranching Productivity vs Area: 1970–2006

(a) Total Pasture Area **(b) Share of Pasture in Region's Farmland**



Source: Census of Agriculture - IBGE.

in pastures implies that most cattle activity in the region is illegal: the North is almost entirely located within the Amazon biome, where by law private properties must maintain native vegetation cover over 80% of total landholding (see Chapter 3). It is because of this expansion that cattle ranching is frequently associated with deforestation in the Amazon in public debate. Cattle ranching in the North illustrates the tension that can arise between production and protection. The P&P strategy offers a practical means to address this tension by promoting increased compliance with environmental regulation within private properties.

Chapter 5 will show that, in the South and Center-West regions the decline in the share of pastures is related to the increase in cropland for soybean. In the Southeast, it was sugarcane that gained terrain over pastures. Soybean and sugarcane have in common the fact that Brazil is a leading producer of both crops, and each thrived in the region with the greater comparative advantage. In the North however, cropland area was small in 1970 and remained so in 2006, implying that the increase in pastureland came from forest area.

A Snapshot of Cattle Ranching: 2006

After looking at the evolution of cattle ranching in Brazil, this section now turns to the picture in 2006, the latest year for which data is available. Table 4.1 presents some numbers that give a sense of the distribution and size of cattle farms and herds.

Column (1) reveals that there were 2.7 million farms with cattle in Brazil, which represented over half of all farms in the country. Furthermore, these farms were unevenly scattered around the country: the Northeast had 36% of all farms, whereas the North and Center-West regions accounted for 8.5 and 9.1% respectively. Column (2) shows the herd size and its distribution. There were 176 million cattle in Brazil, 34% of which were in the Center-West region. The Northeast on the other hand accounted for 14.7% of the herd.[3]

The second part of Table 4.1 looks at "large" farms – that is, farms with herds larger than 50 cattle. Column (3) reveals that only 18% of the cattle farms are large by

[3] It is worth noting that, out of the $(0.81 \times 176,148 =)$ 143 million cattle in large farms, 117 million (82%) are for beef-cattle and 16% are dairy cattle.

Table 4.1: Cattle Ranching in Numbers

	All Cattle Farms		Farms With 50 heads or more			
	(1) # of farms (thousands)	(2) # of heads (thousands)	(3) % of All Cattle Farms	(4) % of all heads	(5) % with confined cattle	(6) % of confined cattle
Brazil	2,678	176,148	18.4	81.3	0.8	2.3
North	228	32,564	43.4	90.0	0.5	0.6
Northeast	973	25,833	8.3	60.2	0.3	0.7
Southeast	544	34,554	24.1	77.9	1.3	3.7
South	689	23,579	9.6	63.9	0.8	2.6
Center-West	244	59,617	47.4	94.5	1.8	3.1

Source: 2006 Census of Agriculture - IBGE.

this measure. In addition, only 8.3% of the Northeastern farms are large, whereas the North and Center-West have large proportions of large farms – 43% and 47%, respectively. Column (4) gives the fraction of the herd concentrated in large farms. Overall, large farms account for 81% of all cattle in Brazil. Again, there are remarkable regional differences. In the Center-West virtually all cattle (94.5%) is in large farms, whereas in the Northeast, this figure is 60%. The last two columns of Table 4.1 show that cattle ranching in Brazil is largely an extensive activity: less than 1% of the farms used confinement, and total cattle living in confinement was at an overall 2.3%. Despite some regional variation, this pattern is consistent across the country.

4.2 Productivity Variation and Pastureland Conversion

In Section 4.1 we saw that cattle farm productivity and pastureland conversion display wide variation across the country. This section takes a closer look at such variations. It shows that **most variation in cattle farm productivity is within regions, as opposed to across regions**. The existing productivity gaps across municipalities of the same region hint at big potential efficiency gains to be realized. **Significant within-region variations also exist in pastureland conversion: over 25% of municipalities within each region follow a trend opposite to that displayed in their region**. In short, the dynamics in pastureland conversion cannot be solely explained by geographical factors.

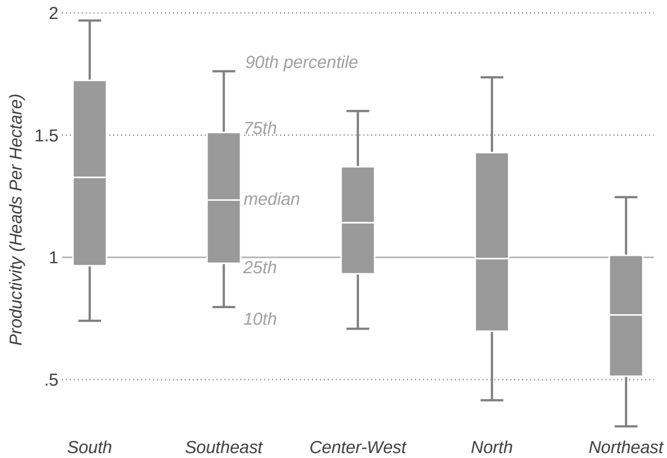
Productivity Variation

In Section 4.1 we saw that cattle productivity displays wide variation across regions: the South achieves 1.5 heads per hectare (HPH), while the Northeast averages 0.8 HPH. This section further examines the variation in productivity, especially variations **within** each region.

Across regions: Figure 4.2 depicts the distribution of productivity for each region. By focusing on municipalities specialized in large-scale cattle ranching, Figure 4.2 reveals slightly different patterns from those observed in Figure 4.1. **Municipalities in the South are still the most productive, with half of them achieving averages above 1.3 HPH**. And whereas 75% of the Southern municipalities achieve more than 1.0 HPH, only 25% of the Northeastern municipalities go past this threshold. These large disparities between the South and Northeast notwithstanding, the differences between the South, Southeast, and Center-West are now much smaller: in the Southeast and Center-West, half of the municipalities achieve an average of 1.2 and 1.1 HPH, respectively.

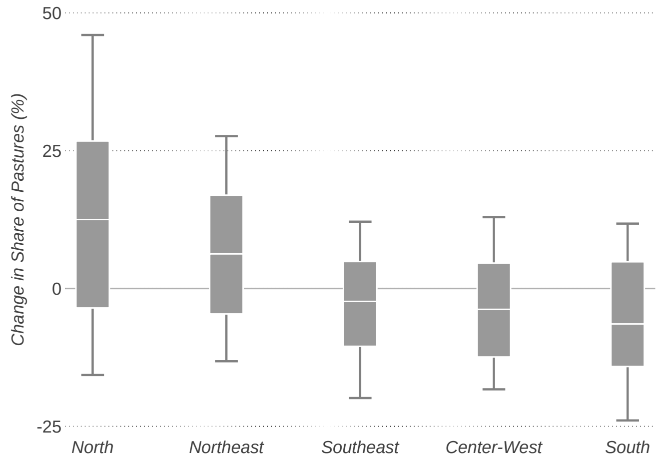
Within regions: Figure 4.2 reveals striking disparities between municipalities **of the same region**. For example, while **the top quarter of the Northern municipalities achieve more than 1.42 HPH, the bottom quarter is under 0.7, more than a two-fold difference**. Even in the region with the least variation in productivity, the Center-West, these thresholds are 0.93 and 1.37 HPH, nearly a 50% difference. Note that these numbers reflect municipality averages; the variation across farms is bound to be even greater.

Figure 4.2 Variation in Productivity: Heads per Hectare, by Region



Notes: The figure shows the variation of cattle farm productivity measured by heads per hectare, by region. The upper whishers show the 90th percentiles of municipalities' productivity; the upper box edges show the 75th percentiles; the white marks show the medians; the lower box edges show the 25th percentiles; and the lower whiskers show the 10th percentiles. Source: 2006 Census of Agriculture - IBGE.

Figure 4.3 Variation in Pastureland Conversion 1985–2006, by Region



Notes: The figure shows the variation of changes in municipalitie's share of pastures on total farmland betweem 1985 and 2006. The upper whiskers show the 90th percentiles of municipalities' productivity; the upper box edges show the 75th percentiles; the white marks show the medians; the lower box edges show the 25th percentiles; and the lower whiskers show the 10th percentiles. Source: 2006 Census of Agriculture - IBGE.

Pastureland Conversion

In Section 4.1 we saw that the North and and Northeast regions experienced increases in the share of pastureland on total farmland since 1970, whereas the rest of the country experienced steady decreases. This section now examines how different these changes were **within** each region by examining data at the municipality level. The focus is on the conversion of pastureland between 1985 and 2005.

Figure 4.3 depicts the distribution of pastureland conversion between 1985 and 2006 for each region using box plots. As expected, most of the Northern and Northeastern municipalities experienced an increase in the share of pastureland. However, in both regions more than 25% of municipalities actually experienced decreases in this ratio. The reverse is true for the other regions: most of the municipalities in the Southeast, South, and Center-West regions saw the proportion of pastureland decrease while in approximately 25% of municipalities pastureland as fraction of total farmland actually increased.

4.3 Technology and Institutions

Technology and institutional factors are important drivers of production and land use decisions. This section explores the relationships between two institutional drivers – land rental markets and cooperatives – and three technological drivers – technical assistance, rotational grazing and lime usage – of cattle farm productivity and pastureland conversion. The results show that the importance of these drivers cannot be understated. In fact, our results show there are opportunities to increase productivity, particularly through improvements in land rental markets, technical assistance, lime usage, and rotational grazing. For example, it's interesting that so little farmland is under lease contracts since holdings under these contracts are more productive than those operated by their owners.

Productivity

For each productivity driver, our analysis splits municipalities into two groups: one "low-adoption" group and one "high-adoption" group, so that each group has the same number of municipalities. We then calculate and compare the average productivity in each group. Table 4.2 summarizes this section's findings.

Table 4.2: Productivity Drivers: Institutions and Technology

	Average Productivity in Municipalities where Driver is...	
Driver	Low	High
Land Rental Markets	1.00	1.24
Cooperatives	1.14	1.10
Technical Assistance	0.99	1.27
Rotational Grazing	1.05	1.19
Lime Usage	0.97	1.27

Notes: each table row shows average HPH in municipalities where the corresponding driver is below and above the median distance. HPH is heads of cattle in large cattle farms divided by hectares of pastures in those farms. The differences in the two columns is statistically significant at the 1% level. We consider only municipalities in which cattle ranching is a significant activity, meaning that the share of pastureland is at least 24 percent of farmland, leaving us with 2879 municipalities.

Land rental markets A well-functioning land rental market ensures that a land holder who is not as productive as her competitors, can rent out her holding to someone who can achieve better results. Hence, healthy land rental markets can have significant impacts on land productivity. We take rental rates as a measure of a well-functioning land rental market, and explore the association with cattle farm productivity. The first row of Table 4.2 presents the results. In the group of municipalities where a low fraction of the land is leased, average productivity is 1.0 HPH. In contrast, in those municipalities with relatively more active land rental markets, productivity averages 1.24 HPH, or 24% higher. In the typical municipality however, only 3.4% of pastureland is leased. Given the extensive nature of cattle ranching, and the low fixed capital investments in farms, it is intriguing that this ratio is so low.

Cooperatives Cooperatives form an important institution to organize agricultural production. As we will see in Chapter 5, cooperatives are associated with productivity gains in most crops. However, in large-scale cattle ranching, this does not seem to be the case. There is little productivity difference between municipalities above and below that threshold. In fact, large-scale cattle ranching is slightly (3.5%) **less** productive in municipalities in which cooperatives are more common.

Technical Assistance Turning to technological factors, the third row of Table 4.2 shows that access to technical assistance is correlated with greater productivity among large scale cattle ranches. In municipalities with little provision of technical assistance, productivity averages 0.99 HPH. This figure jumps to 1.27 HPH when technical assistance is more widely available, a 28% increase.

Rotational Grazing Rotational grazing consists of moving cattle into rested areas to allow for better forage growth. It therefore introduces a trade-off between leaving areas to rest and making them more productive. Table 4.2 shows that it pays off. Municipalities with above-median usage of rotational grazing achieve 1.19 HPH, while below-median municipalities average 1.05 HPH, a 13% drop in productivity.

Lime Lime is an important input in soil stabilization, and is more relevant in the Center-West region because of its acidic soil type. Municipalities with above-median lime usage achieve average productivity levels 1.27 HPH, while this figure is 0.97 HPH for below-median municipalities, amounting to a 31% difference in productivity.

Land conversion

This section now turns to assess the extent to which the institutional and technological factors analyzed in Section 4.3 impacted pastureland conversion between 1985 and 2006. Figure 4.1 shows that the North and Northeast regions increased their share of pastureland in the 1985 to 2006 period, whereas the other regions saw their share of pastureland decrease. Within each region however, some municipalities changed their shares of pastures more than others, as Figure 4.3 shows. This section explores the impacts of land rental markets, cooperatives, and lime usage on the municipalities' changes in share of pastureland. Much like in Section 4.3, municipalities are divided into two groups, but this time according to their adoption levels in 1985. The section, then, discusses how the share of pastureland changed for each of those two groups between 1985 and 2006.

Figure 4.4 depicts the impacts of land rental markets (top panel) and cooperatives (mid panel) on the share of pastureland on total farmland (bottom panel), by region. Municipalities with a high share of land under rental in the North region increased their share of pastureland by 12%, whereas municipalities with a low share of land under rental increased their share of pastureland by 5%. The Northeast follows the same pattern. In the Southeast and South, land under rental had very little or no effect. Finally, in the Center-West municipalities with a high share of land under rental **decreased** their shares of pastureland when compared to municipalities with a low share of land under rental.

Figure 4.4 also reveals that the fraction of farms associated with cooperatives in 1985 had impacts on pastureland conversion only in the Southeast and Center-West regions. Municipalities in which a relatively high fraction of farms were associated with cooperatives saw the share of pastureland decreasing more than those municipalities with low cooperatives coverage.

Lastly, Figure 4.4 reveals the different impacts of lime usage across regions. In the North and Center-West, municipalities with high adoption of lime in 1985 converted less farmland into pastureland in the 1985–2006 period. The opposite is true for the South and Southeast. The degree of lime usage in Northeast had no apparent impact on land conversion.

In sum, these numbers show that better access to good institutions and technology enabled producers in each region to pursue their best available agricultural activity. For example, municipalities in the Center-West with good access to cooperatives, lime, and well-functioning land rental markets, saw their share of pastureland decrease, implying that producers in those municipalities favored crop farming relatively to cattle ranching. Although these data do not show into which crop farmers converted their lands, the next chapter will present data suggesting it was soybean, the leading agricultural exporting commodity in Brazil.

4.4 Financing

This section starts by describing financing in the cattle ranching industry. **Subsidized credit obtained through commercial banks represents 88% of the external financing to cattle ranchers.** The **most productive and dynamic regions in the country** – the North and the South – **rely less on subsidized credit than other regions**. It then goes on to analyze the relationships between financing and productivity and land conversion. **External financing has significant impacts on the productivity of cattle farms**. In addition, **it was an important driver of pastureland conversion between 1985 and 2006, especially in the Center-West by enabling cattle ranchers to intensify production, freeing up land for other activities. In the North however, access to financing in 1985 bears little correlation with pastureland conversion, hinting at different regional dynamics.**

Cattle Ranching Financing

The federal government provides most of the rural credit in Brazil through an umbrella program, the Agricultural Plan (Plano Agrícola e Pecuário, PAP). The PAP offers not only credit, but also an array of risk management and insurance mechanisms, all of which are subsidized. The program's budget increased steadily in the 2000's, jumping from BRL 20 billion in 2002 to BRL 136 billion in 2013. For cattle ranching specifically, credit grew at an annual rate of 9.2% between 2002 and 2010.

Table 4.3 presents the distribution of credit volume, by region and by credit source as reported by cattle ranchers. Commercial banks provide 88% of the credit – this is how most of the PAP's budget is channeled. As Chapter 5 will show, this figure is much higher than that for large-scale crop farming.

Table 4.3: Share of Credit Volume, by Source of Credit and by Region (%)

Region	Source of Credit (%)			
	Banks	Credit Coopera-tives	Suppliers/ Buyers	Other
Brazil	87.80	4.03	6.27	1.91
North	84.59	0.58	13.15	1.69
Northeast	89.58	0.92	8.14	1.36
Southeast	89.92	5.58	1.89	2.61
South	84.20	7.97	6.49	1.35
Center-West	89.00	1.90	7.16	1.94

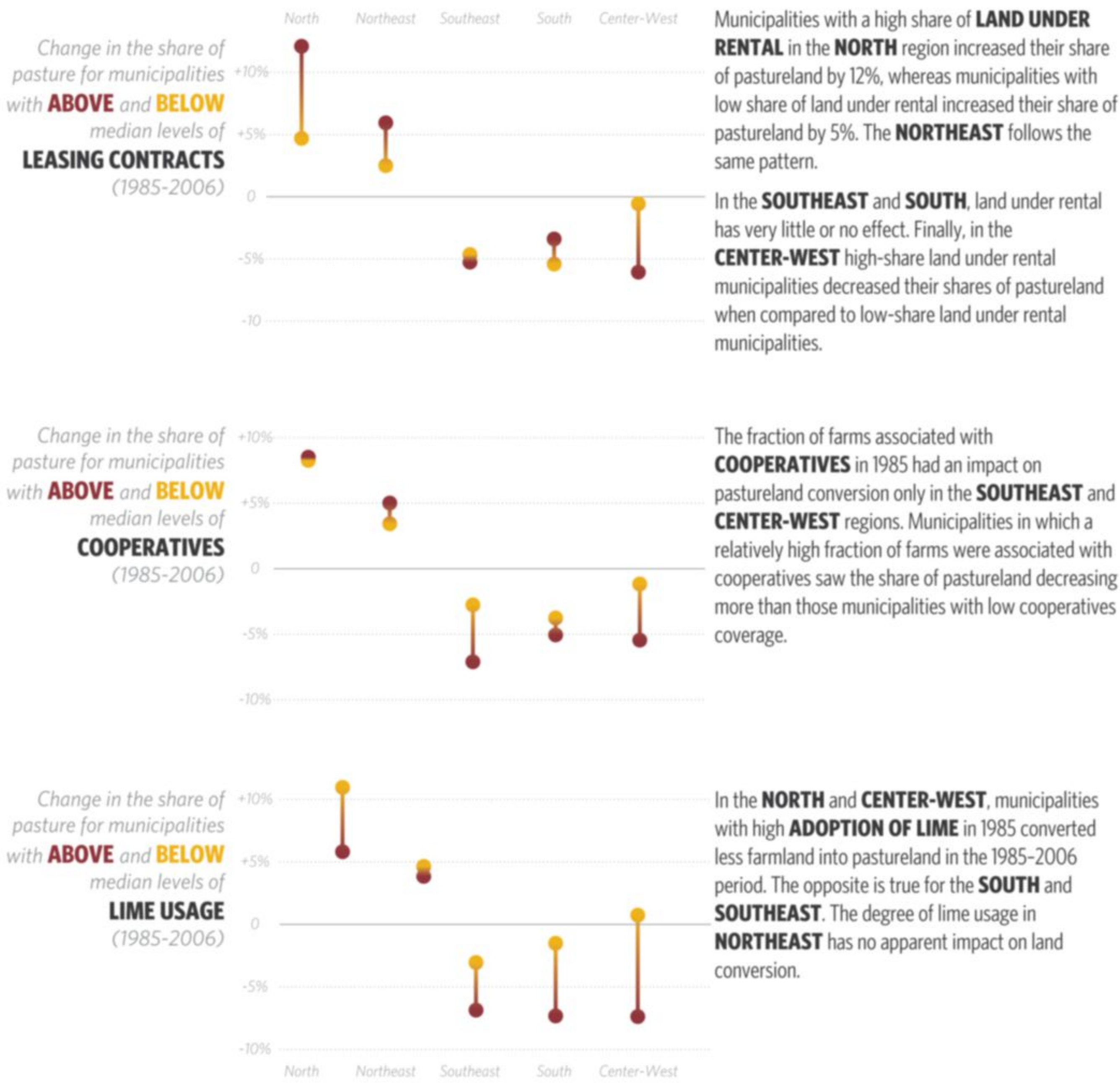
Source: 2006 Census of Agriculture - IBGE. Notes: Share of credit value that is granted by each source.

It is interesting to note that banks are relatively less important in the North and in the South – respectively, the most dynamic and most productive cattle ranching regions, as seen in Section 4.1. In the North, cattle ranchers get a sizable fraction of their external financing from suppliers, whereas in the South cooperatives also play an important role in providing credit.

Financing and Productivity

Financing affects farm productivity by allowing farmers to buy higher quality materials and equipment, as well

Figure 4.4 Pastureland Conversion 1985–2006: Institutions



Source: Census of Agriculture - IBGE.

as adopting new technologies. For example, one important input for cattle farms is the herd's genetics; external financing enables farmers to buy new breeds and use artificial insemination. Recovery of degraded pasture is also an expensive investment that needs external financing, and can boost farm productivity.

Table 4.4 provides a comparison between municipalities with above-median and below-median access to external financing. Two measures are used – average credit per hectare and the fraction of farms taking credit. The average productivity of municipalities in which farmers make relatively more use of external financing per hectare are is 1.29 HPH, compared to 0.95 HPH in below-median municipalities, a 36% difference.

Table 4.4: Productivity Drivers: Financing

	Average Productivity in Municipalities where Driver is...	
Driver	Low	High
Credit Per Hectare	0.95	1.29

Notes: table shows average HPH in municipalities where credit per hectare is below and above the median distance. HPH is heads of cattle in large cattle farms divided by hectares of pastures in those farms. The differences in the two columns is statistically significant at the 1% level. We consider only municipalities in which cattle ranching is a significant activity, meaning that the share of pastureland is at least 24 percent of farmland, leaving us with 2879 municipalities.

Financing and Land Conversion

This section examines the relationships between external financing availability in 1985 and land conversion between 1985 and 2006. Again, because of the different trends in the share of pastures across regions, the analysis is done by region.

Figure 4.5 presents the results. The figure uses credit per hectare as a measure of access to external financing, which appears to have had a significant impact pastureland conversion only in the Center-West region; the differences between municipalities with high and low financing usage are small and not statistically significant in the other regions. In contrast, Center-Western municipalities with high access to external financing decreased their share of pastureland between 1985 and 2006.

4.5 Infrastructure and Marketing

Good infrastructure and links to both upstream and downstream markets are important productivity drivers. In cattle ranching, slaughterhouses are a key link in the production chain, and one immediately crucial for cattle farms. We therefore examine the relationships between productivity and the distance between farms and slaughterhouses. Due to data limitations, we cannot assess impacts of slaughterhouses on land conversion between 1985 and 2006. Chapter 5 takes a more in-depth look at seaports and roads, which are more relevant for crop farming due to the relative importance of exports.

Table 4.5 shows that cattle farms located in municipalities closer to slaughterhouses achieve productivity levels of 1.28 HPH. In municipalities farther away from slaughterhouses, farms achieve productivity levels of 0.96 HPH, a 25% drop.

Table 4.5: Productivity Drivers: Infrastructure

	Average Productivity in Municipalities where Driver is...	
Driver	Low	High
Kms to Nearest Slaughterhouse	1.28	0.96

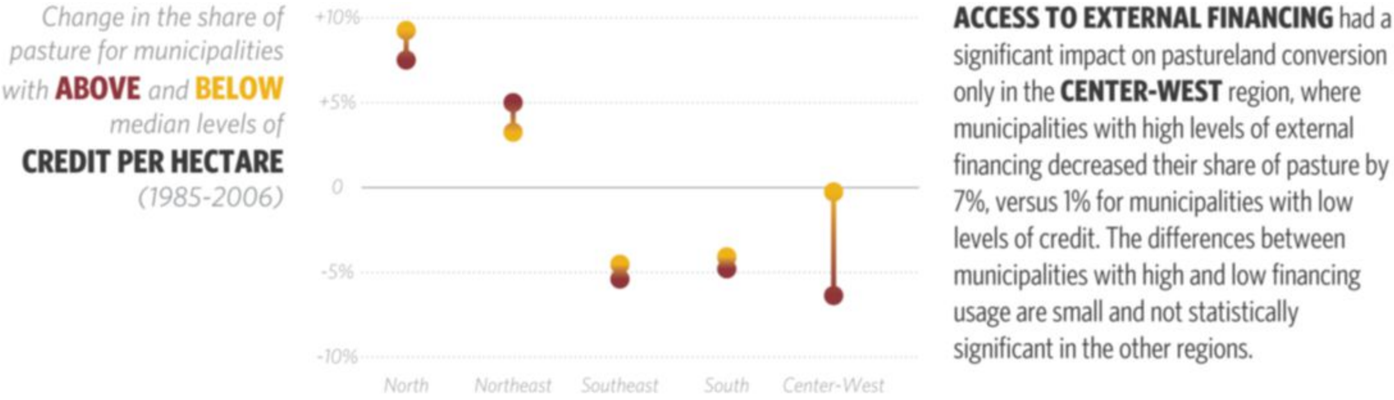
Notes: table shows average HPH in municipalities where distance to the nearest slaughterhouse is below and above the median distance. HPH is heads of cattle in large cattle farms divided by hectares of pastures in those farms. The differences in the two columns is statistically significant at the 1% level. We consider only municipalities in which cattle ranching is a significant activity, meaning that the share of pastureland is at least 24 percent of farmland, leaving us with 2879 municipalities.

4.6 Policy Implications

This chapter has examined productivity and land conversion patterns in Brazilian cattle ranching. Among other implications for public policy, two are particularly important to underline.

First, cattle farm productivity displays wide variations even after accounting for geographic characteristics. Improving cattle farm productivity is a key step to freeing up land to other uses, including conservation. There is room for policy to promote adoption of key technologies, such as rotational grazing and lime usage, which can have a quick and yet powerful impact on productivity. Relaxing certain institutional constraints, such as improving the functioning of land rental markets, may prove challenging on the short-term, but

Figure 4.5 Pastureland Conversion 1985–2006: Financing



Source: Census of Agriculture - IBGE.

will have long-standing benefits from a P&P standpoint. It is noteworthy that overall cattle farm productivity grew at half the pace of crop farming productivity, as Chapter 5 shows; this means there is sizable room for productivity growth, and public policy can play a considerable role in achieving this goal.

Second, the North region's trajectory is impressive in terms of production, but worrisome from a protection standpoint. Such tension is best addressed by public policy. A P&P strategy enables policy to simultaneously tackle these challenges – policy must support growth in production while increasing the cost of clearing native vegetation to counter the deforestation pressures arising from increased agricultural productivity. As discussed in Chapter 3, increased protection in Brazil must be pursued via greater enforcement of environmental legislation within private rural properties, as well as through the adoption of market-based incentives for preservation. The fact that the North displays wide variation in farm productivity increases the scope and the potential for success of such a P&P strategy.

Chapter 5

Large-Scale Crop Farming

Chapter Preview

Large-scale crop farming in Brazil is important not only to the national economy, but in the world agricultural sector. The country ranks among the world's three largest producers of sugarcane, soybeans, and maize. The crop farming sector has experienced a fast expansion in the past decades and is the most dynamic sector of the Brazilian economy: the net production value of crop farming grew at an average rate of 5.05% per year between 2000 and 2010, compared with the country's GDP growth of 3.64% per year in the same period.

In Brazilian large-scale crop farming, **productivity levels vary significantly across regions and crops**. This is due to **disparities in the availability of raw materials and technologies**. Financial services also display an uneven pattern: **Credit and insurance, essential to agriculture, are frequently very limited**. Similarly, **poor infrastructure sharply limits agricultural production**: regions distant from consumer markets often fall short of achieving high productivity levels due to bad infrastructure.

This chapter starts by describing productivity trends and patterns in the large-scale crop farming sector in Section 5.1. Section 5.2 analyzes technological and institutional drivers of productivity. Section 5.3 turns to financing and insurance, while Section 5.4 discusses infrastructure drivers. Finally, Section 5.5 outlines key policy implications.

5.1 Productivity: Trends and Patterns

This section starts by presenting a snapshot of the large-scale crop farming sector. **Soybean, maize, and sugarcane account for over half of total cropland in Brazil.** Soybean is concentrated in the Center-West and in the South, while sugarcane's main production region is the Southeast and maize is more dispersed over the country. Sugarcane has highest physical productivity and gross value generated per hectare, while soybean achieves a high total production value despite low productivity in all regions. Maize displays the highest variation both in terms of gross value and of physical output per hectare.

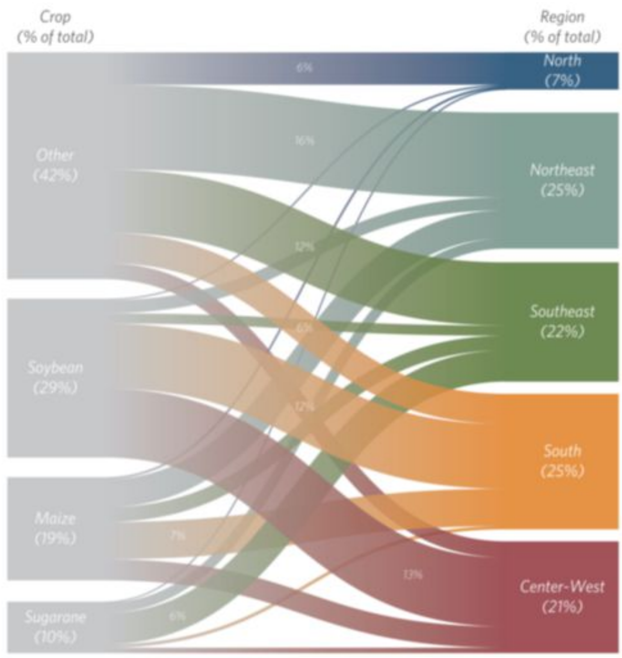
We then present productivity trends and patterns for these three main crops. As a whole, the **large-scale crop farming sector experienced a remarkable expansion both in terms of area and productivity in the past decades**. **Soybean production expanded steadily in all regions while variations in productivity levels between regions decreased**. **Sugarcane underwent a major expansion in the Southeast and a recent expansion in the Center-West**. Finally, **maize stands as a heterogeneous crop: It expanded in some regions but contracted in others** — suggesting no clear pattern due to technology improvements or international prices — and **its productivity levels vary widely across Brazil.**

A Snapshot of Crop Farming in Brazil

Figure 5.1 depicts the allocation of Brazilian cultivated land across crops and regions. The horizontal axis shows the share of each crop out of total cropland. Soybean alone accounts for nearly 30% of the country's cropland; add maize and sugarcane and this figure rises to 58%. The vertical axis shows how each crop is distributed across the country's regions. For example, sugarcane is mostly a Southeastern business, whereas soybean is evenly split between the South and Center-West. Finally, the numbers within each rectangle represent the share of each region and crop out of total Brazilian cropland. For example, by adding the shares related to the North, one can see that the region accounts for less than 7% of the country's cropland.

Figure 5.2 shows how productivity is dispersed both across regions and crops, in terms of physical output and gross production value. A few patterns emerge from this picture. First, the value of sugarcane per hectare is

Figure 5.1 Main Crops: Area by Region



Source: 2006 Census of Agriculture - IBGE. The figure shows how the nearly 60 million hectares of cropland in 2006 were divided across crops and regions.

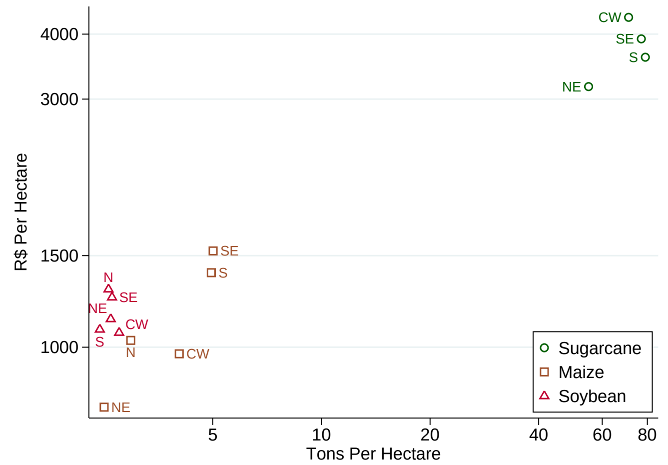
at least twice the value of both soybean and maize: in the Northeast, the least productive region for sugarcane, farmers achieve more than BRL 3,000 per hectare of sugarcane. In contrast, one hectare of maize in the Southeast yields BRL 1,500. Secondly, physical productivity for maize is widely dispersed across regions: in the Northeast farmers achieve 2.5 tons per hectare, whereas in the Southeast one hectare yields 5 tons of maize. Thirdly, soybean physical productivity is fairly constant across all regions: Value per hectare of soybean in the South and Center-West are similar, while other regions do not produce enough of this crop for their slightly higher prices to be relevant (recall Figure 5.1).

Evolution of Crop Farming in Brazil: an Overview

Figure 5.3 depicts the evolution of physical productivity and land area used by the three main crops between 1970 and 2006, by region.

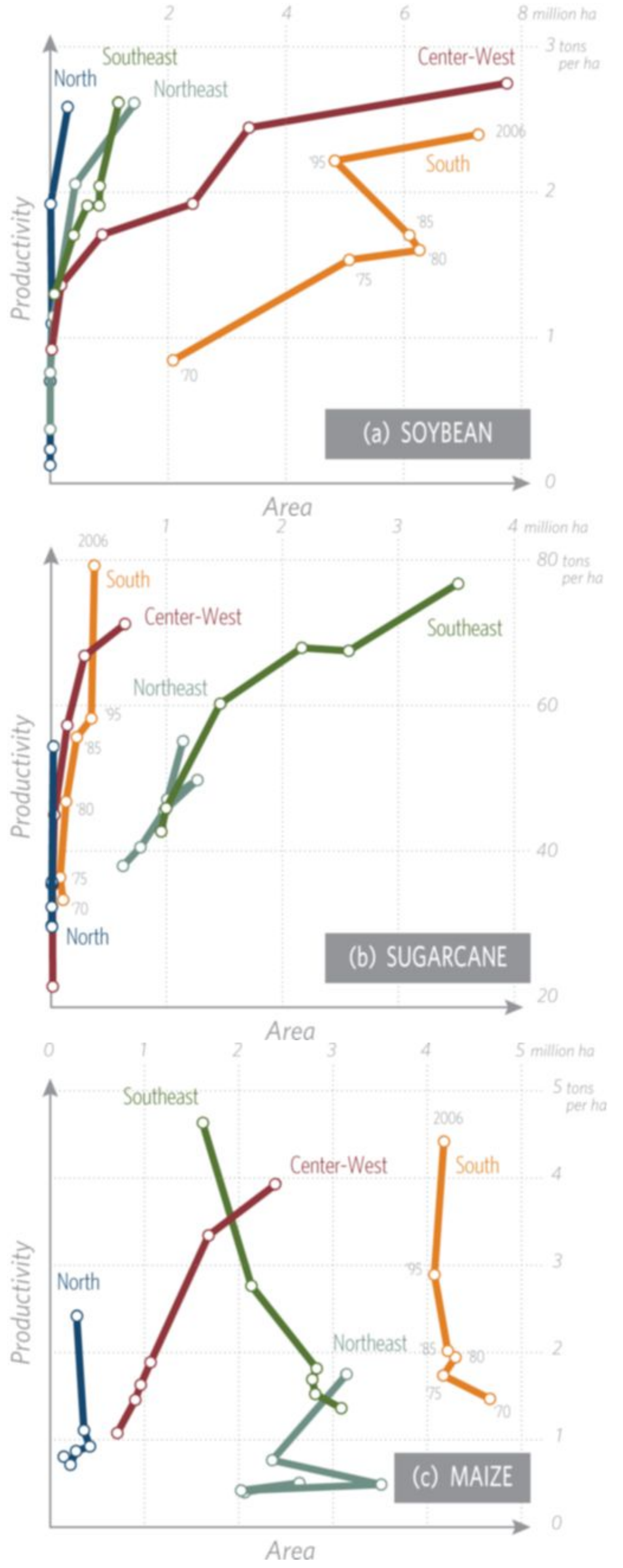
Land used for soybean production has expanded across all regions, while productivity levels have converged. Until 1975, only the South had significant soybean production. The Center-West began producing in 1980, with productivity levels slightly higher than those of the South. Production grew in both regions until 1996; by 2006, the Center-West displayed both better

Figure 5.2 Main Crops: Productivity, by Region



Source: 2006 Census of Agriculture - IBGE. Note: The figure shows productivty in tons per hectare and gross revenues per hectare, by region and crop.

Figure 5.3 Crop Farming Productivity vs Area: Selected Crops, 1970–2006



Source: Census of Agriculture - IBGE.

productivity and a larger cultivated area than the South, which experienced a 4-fold expansion in cultivated area.

Sugarcane's trajectory was marked by a widening gap between the Northeast and the Southeast, both in terms of cultivated area and productivity. Until 1975, these were the only two regions with any significant production of sugarcane, and the productivity difference between them was relatively small. The productivity gap between the two regions started increasing in 1975 and, as of 2006, the Northeast was the least productive of the five regions in the country. Although production was highly concentrated in the Southeast, due mostly to high-quality land and good infrastructure in the state of São Paulo, the Center-West started showing signs of its potential for sugarcane expansion.

The evolution of maize production is remarkably different from those of other crops. It expanded in some regions, while contracting in others between 1970 and 2006. In addition, while the Southeast achieves nearly five tons per hectare, the Northeast averages less than two tons per hectare. To put that figure in perspective, two tons per hectare is around what other regions achieved in the 1980s.

5.2 Technology and Institutions

This section analyzes how technology and institutional factors affect crop farm productivity. **Established technologies, such as fertilizers and mechanical harvest, have a large impact on productivity, and**

adoption levels of these technologies is high at the national level. However, **they vary significantly across regions and crops**. **Adoption rates are lower for modern technologies**, such as improved seeds and the direct planting system, indicating there is room for public policy to help address barriers to the spread of new production methods. **Institutional features also play an important role**: well-functioning land rental markets, availability of technical assistance to farmers, and the presence of producers' cooperatives are associated with high yields, and are also unevenly distributed across regions and crops.

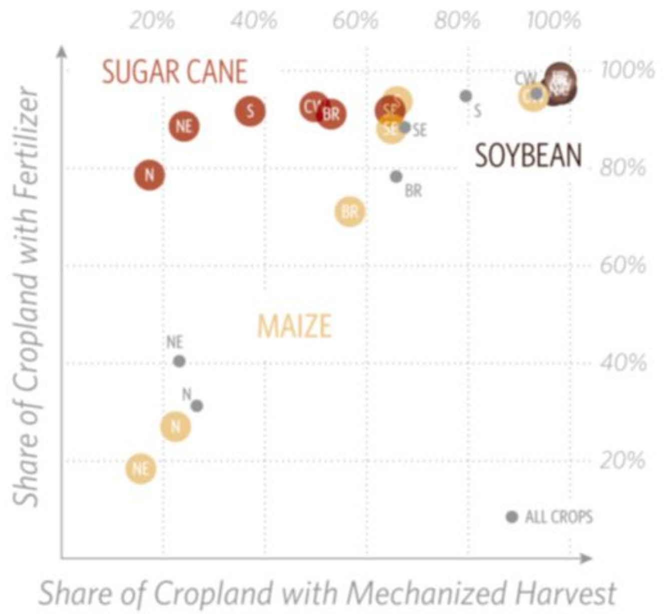
This section initially considers two established technologies and production methods: mechanized harvest and the use of fertilizers. It then turns to new technologies like new seeds and the direct planting system, whose under-adoption is related to problems in the spread of these new methods. To assess the impacts of these various productivity drivers, the analysis proceeds by splitting municipalities into two groups: a "low-adoption" and a "high-adoption" group, each with the same number of municipalities. Average productivity in each group is then compared. Table 5.1 presents this section's results; each driver is then discussed separately.

Table 5.1: Productivity Drivers: Technology and Institutions

	Average Productivity in Municipalities where Driver is...	
Driver	Low	High
Fertilizers	1,460	2,739
Mechanical Harvest	1,890	2,353
Direct Planting	1,999	1,982
Modified Seeds	1,935	2,305
Lease Area	1,821	2,159
Technical Assistance	1,575	2,635
Coops	1,704	2,519

Notes: The table shows average productivity - crop production value per hectare (BRL) for municipalities below and above the median of the variable shown in the first column. All differences in mean are statistically significant at the 1% level.

Figure 5.4 Technology Dispersion, by Region



Source: 2006 Census of Agriculture - IBGE.

Mechanical Harvest and Fertilizers The first two rows in Table 5.1 look at well-established technologies: mechanized harvest and fertilizers. Both are associated with higher productivity levels. Municipalities in which fertilizers are more widespread are 87% more productive than those in which fertilizers are less common. This figure is 24% in the case of mechanized harvest.

The distribution of mechanical harvest and fertilizers across regions and crops is depicted in Figure 5.4. Overall, 65% of all cropland is harvested mechanically and 78% uses fertilizers. However, there are wide disparities both across crops and regions, especially in mechanization. At one end of the scale, less than 20% of the maize crops use mechanization and fertilizer. At the other end, soybean crops are almost fully mechanized and fertilized in all regions.

The high use of these technologies throughout Brazil suggests that public policy should focus on those regions and crops with low adoption rates. In other words, **encouraging the spread of mechanical harvest and fertilizers in the North and in the Northeast, as well as among maize farmers, should be the focus of public policy**.

Improved Seeds The development of seed varieties has been a major factor behind productivity gains. Improved seeds were particularly important as the agricultural frontier moved into different soil types and climates (see Box 4.1). Table 5.1 shows that municipalities with high usage of improved seeds have productivity levels 20% higher than municipalities with low usage.

Table 5.2 shows how adoption of improved seeds varies across regions and crops. Overall, 58% of the country's harvested area was reported to use some kind of improved seed. While soybean crops make heavy use of improved seeds in all regions, maize stands out with a wide variation in adoption: more than 85% of maize crops in the South and Center-West use improved seeds, while in the Northeast this figure is 12%. Such disparity hints at the need for region-specific policies to increase maize productivity by bringing state-of-the-art technologies to areas where production methods are out-of-date.

Box 4.1 – Soybean and New Technologies

Soybean cultivation illustrates the importance of new technologies in Brazilian agriculture and sheds light on the upcoming challenges: enhanced seeds and the direct planting system (DPS) must be combined in order to increase crop farm productivity, as described in Bustos et al. (2013).

To adopt no-tillage techniques such as the DPS, farmers need to use herbicides; the main advantage of tillage is to rid the soil of weeds that otherwise can only be destroyed through the use of weedkiller. However, traditional soy seeds are not resistant to herbicides, which triggered the development of genetically-engineered (GE) seeds. The use of GE seeds then enabled soy farmers to adopt the DPS. Productivity gains stemmed from the improved seeds as well as from DPS itself.

The Brazilian government authorized the use of genetically-engineered (GE) soy seeds in 2003, seven years after the first generation was commercially released in the United States. In 2006, GE seeds were used in 46.4% of total soy cultivated area in Brazil, and reached 85% in the 2011-2012 season. The major productivity gains induced a large expansion in the soy harvested area: it took 20 years to increase this area from 8.7 to 13.6 million hectares between 1980 and 2000, and then this increase accelerated to reach 21.6 million hectares in 2010. This was one of the main drivers that allowed Brazil to become the second largest soy producer in the world.

This example shows that public policy should focus not only on the development of individual agricultural technologies, but also on the interaction among different technologies so as to remove obstacles to adoption and facilitate the spread of new production methods.

Table 5.2: Share of Cropland with Improved Seeds (%)

Region	All Crops	Sugarcane	Maize	Soybean
Brazil	58.1	13.0	64.0	87.9
North	22.9	58.2	24.6	83.3
Northeast	18.0	10.1	11.8	83.3
Southeast	42.2	13.4	72.9	83.7
South	82.2	13.4	89.6	91.1
Center-West	80.6	14.0	86.7	86.6

Source: 2006 Census of Agriculture - IBGE. Notes: table shows adoption of improved seeds in cropland under temporary crops across regions and crops. Temporary crops, as opposed to permanent crops, require year-to-year replanting. Soybean, maize and sugarcane are all temporary crops.

Technical Assistance The availability of technical assistance has a direct impact on productivity as farmers learn how to make better use of any given supplies; again, this is quite relevant in Brazil due to poor educational standards. Municipalities with high levels of technical assistance achieve significantly higher output than those with low levels of assistance: the gap is 48%.

The availability of technical assistance also displays wide variations across regions and crops. Table 5.3 reveals that 24.5% of Brazilian farmers received some kind of technical assistance in 2006. This figure reached 57% in the South region, and only 7.8% in the Northeast. 78% of soy producers received assistance, compared to only 22% of maize farmers. In sum, the disparities in technical assistance follow similar patterns as disparities in productivity.

Table 5.3: Share of Cropland where Technical Assistance was provided (%)

Region	All Crops	Sugarcane	Maize	Soybean
Brazil	24.5	35.3	22.6	77.8
North	14.2	19.5	16.8	58.6
Northeast	7.8	16.2	7.6	76.8
Southeast	27.1	36.4	25.2	82.6
South	57.5	48.9	54.3	77.4
Center-West	38.9	34.5	37.7	82.1

Source: 2006 Census of Agriculture - IBGE. Note: table shows the fraction of cropland under temporary crops that received technichal assistance in 2006. Temporary crops, as opposed to permanent crops, require year-to-year replanting. Soybean, maize and sugarcane are all temporary crops.

Direct Planting System The Direct Planting System (DPS) is a no-till farming technique, and an important recent development in agriculture. The DPS has virtually no upfront costs and results in higher crop yields, lower overall costs and lower carbon emissions - a more detailed account of the system is presented in Box 4.2. Table 5.1 shows that municipalities with high DPS adoption achieve crop farm productivity levels that are 11% higher than municipalities with low adoption.

The DPS was first introduced in Southern Brazil in the early 1970's. Overall, use of the DPS covers 32% of the cropland in the country, although only 10% of farmers reported using the system in 2006. The South and the Center-West have relatively high adoption rates with over 50%, while the other regions are all below 13%.

Land rental markets Turning to institutional arrangements, this section considers the impact of land rental markets on productivity. High rental rates indicate a well-functioning rental market, and should lead to higher productivity levels as land can be put to its highest value use regardless of ownership. This is particularly relevant in Brazil, where non-agricultural use of land is pervasive due to a historically unstable financial system. Table 5.1 confirms this intuition: municipalities with above-median prevalence of rentals are 19% more productive than below-median municipalities.

Table 5.4 shows that 12% of temporary cropland, which includes the main crops cultivated in country, was being rented in 2006. This figure is highest in the Southeast (16%), compared to only 5.5% in the North and 6% in the Northeast — suggesting a significant restriction to the rental market in these regions. Moreover, the area of permanent cropland that is being rented is significantly smaller: only 2.5%.

Cooperatives Finally, Table 5.1 reveals the impacts of cooperatives on productivity: municipalities with high shares of association with cooperatives achieve productivity levels 28% higher than municipalities with low association rates.

Once more, temporary crops (which include the main crop products in Brazil) display a higher participation than permanent ones: the share of farmers on temporary cropland associated with a producer's association reached 28%, while the share of farmers on permanent cropland who were part of such an association reached 12.5%. Again, these figures are highest in the South, where nearly 48% of temporary crop farmers reported themselves to be in a cooperative. This suggests that crops with low productivity would benefit from increased access to producers' associations.

Table 5.4: Adoption of Institutional Drivers Across Regions

	Cropland under DPS (%)	Cropland under Rental (%)	Farms Associated to Cooperatives (%)
Brazil	32.2	12.0	28.3
North	7.9	5.5	16.5
Northeast	9.1	6.1	27.9
Southeast	12.5	16.2	19.8
South	52.4	12.6	47.7
Center-West	52.0	12.7	12.7

Source: 2006 Census of Agriculture - IBGE. Notes: Column (1) shows the fraction of cropland under temporary crops in which farmers applied the direct planting system. Column (2) shows the fraction of cropland under temporary crops under rental. Column (3) shows the fraction of farms associated with cooperatives or syndicates. Temporary crops, as opposed to permanent crops, require year-to-year replanting. Soybean, maize and sugarcane are all temporary crops.

5.3 Financing and Risk Management Tools

The financial system plays a central role in the agricultural sector. Credit is essential for farmers, who often need to buy raw materials and machinery to start production — which usually takes months before products reach consumer markets. Insurance and risk management tools can help address the main risks of production — those of output loss and price slumps.

This section shows that **financial tools are essential for agriculture: productivity is positively associated with the availability of external credit** and **negatively correlated with weather risk**. Although the government is the main provider of credit and insurance, **crop farmers are less dependent on subsidized credit from banks and have more access to market mechanisms when compared to cattle ranching farmers**. In particular, international financial markets are accessible to export-oriented crops such as soybean. **Regional arrangements also play a role: crop farmers in the Northeast rely on buyers and suppliers for credit, while cooperatives provide more credit support in the South.**

Financing and Productivity

Table 5.5 shows that farmers in municipalities with above-median access to credit achieve productivity levels 3.8% higher than those in municipalities with low access to credit. Furthermore, farmers in municipalities with relatively high crop risk — measured by rain volatility —

Box 4.2: The Direct Planting System Case

Given the environmental and economic gains of the Direct Planting System, a no-till method which is an important development in agriculture, the spread of the system is a main target of agricultural policy. Currently, adoption levels of this method remain low throughout the country.

The Direct Planting System, however, does not present the usual features that prevent spread of a new technology. Outputs under the Direct Planting System are higher than in traditional farming. It is suitable for more types of soil than traditional farming. Lastly, farmers do not incur significant upfront costs for adopting the method: There is no need for extra machinery or additional workers.

However, farmers must learn a new technique before adopting it. And unlike traditional tillage farming, the Direct Planting System needs to be adapted to specific site conditions.

Assunção et al. (2013) find that social learning — i.e. farmers learning new methods from their neighbors and peers — plays a major role in the spread of the Direct Planting System. Further, in any given municipality in Brazil, similarities or dissimilarities in soil composition directly affect social learning, and thus, the uptake of the technology: The more similar the soil within a municipality, the easier the spread of social learning. This is particularly true for areas with intermediate levels of Direct Planting System adoption where there are enough farmers to share their knowledge with their peers.

These results suggest that frequently used policies may be ill-suited for encouraging the spread of the Direct Planting System. As an example, in order to hit targets for reducing carbon emissions from the agricultural sector, the Brazilian government implemented in 2010 the Low-Carbon Agriculture program (*Agricultura de Baixo Carbono*, ABC), which provides subsidized rural credit to farmers for implementation of the Direct Planting System. However, low-cost credit is not enough to drive Direct Planting System expansion if non-financial restrictions are significant.

Instead, an itinerant training process, moving across municipalities over time, can support the spread of knowledge and adoption. In fact, one of the alternative channels of dissemination shown to have an impact is a system of private training centers, modeled after the original "Clube da Minhoca" (run by the Brazilian Federation of Direct Planting), that frequently work only for a period of time in a given municipality — until it reaches a level of adoption that allows further dissemination to take place autonomously. Our analysis suggests that public policy could follow this private sector example, to raise Direct Planting System adoption levels to where the technique can more easily spread through social learning.

Finally, because learning from peers becomes easier where soils are more similar, efforts to increase adoption can provide an initial spark that is then fueled by social learning. It follows that to be cost-effective public policy should first focus on those municipalities with more uniform soil composition to ensure that social learning can go farthest.

achieve productivity levels 6% *lower* than those with less exposure to weather risk.

Table 5.5: Productivity Drivers: Financing and Risk

Driver	Average Productivity in Municipalities where Driver is...	
	Low	High
Financing per hectare	1,290	2,525
Rain volatility	2,068	1,794

Notes: The table shows average productivity (RS per hectare) for municipalities below and above the median of the variable shown in the first column. All differences in mean are statistically significant at the 1% level.

In Brazil, financial services for agriculture are mostly provided by the public sector. The Agricultural Plan (*Plano Agrícola e Pecuário*, PAP) is the federal government's umbrella program that provides subsidized credit lines and risk management tools to farmers and agribusinesses. The PAP's budget increased quickly in the last decade, from BRL 20 billion in 2002 to BRL 136 billion in 2012, an amount comparable to the disbursements of Brazil's development bank, the BNDES. This is by far the most relevant public policy in agriculture. The large amount of public funds available and the wide scope of the program, which encompasses virtually all sectors of agricultural production, are the government responses to the limited number of private instruments available to farmers.

Although underdeveloped, the private market performs three roles. First, the PAP's budget is channeled through both public and private commercial banks throughout the country. Table 5.6 presents how credit reaches farmers and agribusinesses. Overall, 73.2% of crop-oriented credit is provided through commercial banks. It is worth noting that this figure is much lower than that for cattle ranching, as described in chapter 4.

Secondly, some farmers and agribusinesses have access to private markets. Table 5.6 reveals that farmers in the Center-West obtain 26% of their external financing from sources that include traders and foreign financial markets. This is due to the fact that the Center-West specializes in soybean, which is an export-oriented crop — 42% of the production is exported. For maize, on the other hand, 81% of the total output is sold in the domestic market: accordingly, maize farmers have little access to international financial services.

Finally, Table 5.6 shows that a significant portion of credit is obtained privately from business partners (both suppliers and buyers) or through cooperatives. In the Northeast, over 25% of credit is obtained from business

Table 5.6: Share of Credit Volume, by Source of Credit and by Region (%)

Region	Source of Credit (%)			
	Banks	Credit coopera-tives	Suppliers/ Buyers	Other
Brazil	73.18	4.15	11.56	11.11
North	84.22	2.87	6.06	6.84
Northeast	67.79	0.92	25.53	5.76
Southeast	87.2	5.03	3.56	4.2
South	83.46	7.75	7.85	0.95
Center-West	53.77	1.92	17.74	26.57

Source: 2006 Census of Agriculture - IBGE. Notes: Share of credit value that is granted by each source.

partners, while in the Center-West this figure is 18%. In the South, 8% of the credit is obtained through cooperatives.

5.4 Infrastructure and Commerce

Ports, roads and storage facilities are key ingredients to agriculture production. Good roads, for instance, effectively shorten distances to consumer markets. This section shows that **infrastructure has a large impact on productivity, but crop farmers cannot realize efficiency gains due to poor storage and transport systems. The best ports for exporters are not well-served by the road system**. This is aggravated by inadequate storage capacity, which increases the pressure on the transport system.

Table 5.7 assesses the impact of infrastructure on productivity. Municipalities closer to state capitals have productivity levels 9% higher than those municipalities farther away. In addition, municipalities closer to ports are 24% more productive than more distant municipalities.

Table 5.7: Productivity Drivers: Infrastructure

Driver	Average Productivity in Municipalities where Driver is...	
	Low	High
distance to state capital	2020	1851
distance to ports	2139	1726

Notes: The table shows average productivity (BRL per hectare) for municipalities below and above the median of the variable shown in the first column. All differences in mean are statistically significant at the 1% level.

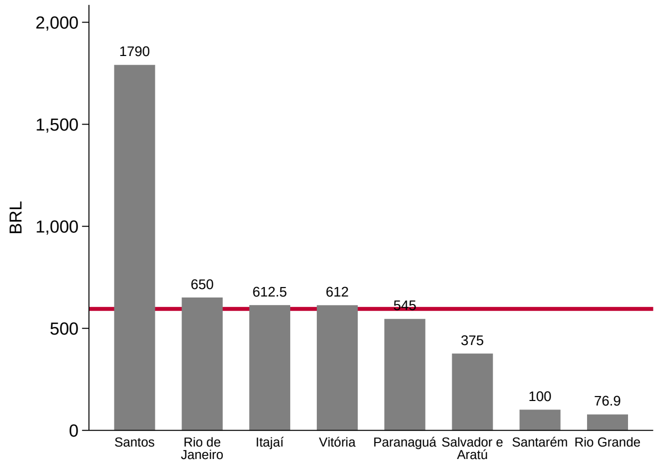
The fact that distance to ports has a higher impact than distance to state capitals is linked to the fact that a sizable fraction of large-scale crop farming is export-oriented.

How well does current infrastructure support crop sales in Brazil? The answer to this question is based on the the current state of storehouses, roads, and ports.

Storehouses Brazilian farms have little storage capacity: only 14% of the storage capacity is located within farms. In countries that are large grain producers, such as Argentina, the USA, and France, this figure is around 30% to 60%. Furthermore, the country's overall storage capacity is at 80% of the harvested amount, which is way below the Food and Agriculture Organization recommendation of 120%. *Despite* poor storage facilities, Brazil has become one of the most prominent agricultural producers in the world.

Transportation: roads and seaports The following figures summarize the current situation of transportation costs in Brazil: it costs USD 123 to carry a ton of soybean through 1,190 miles of highway, from Sorriso, MT to Santos. In the USA, traveling the 1,343 miles from Davenport, IA to New Orleans costs USD 44 per ton of soybean.

Figure 5.5 Vessel's Berthing Rate



Source: ANTAQ.

To better understand why transportation costs are so high in Brazil, it is worth looking at the combination of ports and roads. Currently, the Southeastern port of Santos is the country's main destination of grain output for export, due to good road infrastructure. However,

Figure 5.6 Distance to Ports

Source: SECEX (2012). Note: the map shows the road connections from Cuiabá, MT to the ports of Santarém, PA and Santos, SP. Good roads connect Cuiabá to Santos in 1,600 km. From Cuiabá to Santarém, bad roads force trucks to travel 3,000 km.

Santos has a vessel berthing rate of BRL 1,790 (see Figure 5.5). This is 1,800% greater than the vessel berthing rate at Santarém, which is located in the North, and closer to foreign consumer markets such as the USA and Europe. Santarém is not currently used as an offloading point due to inadequate road infrastructure (see Figure 5.6). Industry estimates claim that a road between Cuiabá, MT and Santarém would reduce transportation costs by 53.5%.

It is worthwhile to note that although the main port for grains is public (Santos), private ports have become more important for the Brazilian agricultural sector. The largest private port in the country (Tubarão) was built by Vale do Rio Doce, the largest mining company in Brazil, to export iron ore (in 2007, it was the largest harbor for iron ore in the world). Currently, it is responsible for 11% of the country's maize exports, and for 9% of soybean exports (Santos' shares are 45% and 26%, respectively). This reflects the fact the iron business in the country is vertically integrated, which allowed Vale to build its own infrastructure in order to avoid the poor quality of public ports. Agricultural farming is a more dispersed business; as a consequence, it is more difficult to coordinate efforts to build the necessary infrastructure.

5.5 Policy Implications

This chapter described productivity patterns in Brazilian large-scale crop farming and discussed its most important drivers. The analysis leads to several suggestions for public policy, including the ones outlined below.

Public policy should foster adoption of both established and more recent technologies. Established technologies, such as mechanical harvest or fertilizers, have high adoption levels throughout the country, but are limited in specific regions and crops; hence, public policy should develop local approaches to help increase usage. Adoption of more recent technologies, such as enhanced seeds and the direct planting system, are restricted by different factors: farmers must learn to use them, and eventually adapt them to specific site conditions. Public policy should incentivize different learning methods so as to spread these technologies. Direct technical assistance, tailored to regional characteristics, is an example of such a policy.

Another barrier to productivity is farmers' limited access to credit. The most important public policy for agriculture is a large-scale annual credit bill. However, it is necessary to understand what prevents the financial system from developing so as to design a bill that will complement and foster the private market instead of simply replacing it with public funds. Particular attention should be devoted to the role of local arrangements and to the role of international markets: both have the potential to finance crop farming and to reduce price risks.

Large-scale crop farming is also affected by poor infrastructure, which should be tackled in an integrated approach with cattle ranching activities and small farming. Roads and ports that play a role in relevant production regions should be improved. This includes transportation to both domestic consumer markets and gateways to international markets, since Brazilian large-scale crop farming is significantly integrated into the world economy.

Chapter 6

Small-Scale Agriculture

Chapter Preview

Although they occupy only 24% of total farmland in Brazil, small farms account for 84% of agricultural establishments and employ more than 12 million workers, or 74% of the rural workforce. Moreover, 40% of the income in rural areas comes from agricultural activities (Helfand et al., 2008). At the same time, nearly 40% of the rural population under the poverty line are small-scale farmers, while 46% are agricultural workers without land. Therefore, increasing agricultural productivity, and consequently agricultural revenue for small-scale farmers, can reduce poverty and enhance food security.

This chapter discusses the barriers to productivity gains in small-scale farming. **Small farm productivity varies across and within regions**: cattle ranching is more productive in the South than in other regions, and crop yields are highest in the South and the Southeast. Productivity is positively associated with educational levels: **high school and college are important to crop farm productivity, while elementary education is more relevant for cattle farm productivity**. This suggests that crop farm productivity requires specialized skills that are less necessary for cattle ranching. Alongside education, **technical assistance also has a large effect on the spread of good practices** and is associated with higher productivity in both crop farming and cattle ranching. Lastly, the federal government has a major role in the development of small-scale farming: the main source of credit for small holders is the National Program for the Strengthening of Family Agriculture (*Programa Nacional de Fortalecimento da Agricultura Familiar*, Pronaf). Although credit is one of the most important factors to increase productivity, small-scale farmers are generally reluctant to apply for loan as they fear being unable to repay their debts. This points to the **lack of insurance mechanisms to support small farms** in the event of weather shocks or price slumps. Although public insurance mechanisms linked to Pronaf were created after 2006, there is no comprehensive database to analyze their effects.

The rest of this chapter is organized as follows. Section 6.1 describes the main aspects of small-scale agriculture: land use, key products and productivity variation. Section 6.2 discusses how small farm productivity responds to institutional factors and technology. Section 6.3 presents the main instruments of insurance and credit and examines how they affect yields. Section 6.4 analyses how infrastructure affects productivity. Finally, Section 6.5 outlines key policy implications.

6.1 Small Farm Production

This section describes key aspects of small-scale agriculture in Brazil. **The main crop products of small farms are maize and cassava**, which are sold mostly in the domestic market. The distribution of cattle farming activities is different from large-scale agriculture: **for small farms, dairy production is more important than beef cattle production; for large farms, the opposite holds. For both small and large farms, total cattle farm production represents around 20% of total production**. Productivity varies across regions: **for small farms, cattle ranches are far more productive in the South, while the productivity of crop farms is highest in the Southeast**. Lastly, **productivity variation is very high even within regions**.

Snapshot of Small Farming in Brazil

There is little consensus on the definition of small farms. The present analysis considers the same definition the Brazilian government has used since 2006.[1] A farm is considered small if the following criteria are met: (i) farm size should be no larger than four fiscal modules;[2] (ii) the share of the farmer's income provided by the rural establishment should be no higher than a predetermined threshold; (iii) it should use predominantly family labor. This definition is used by the government to target agriculture policies such as credit and insurance to small farms.

Table 6.1 reveals the importance of small-scale farming in the Brazilian economy. The sector employs more than 74% of total workforce in agriculture and covers 24% of farm area: small farms are the main driver of rural employment. However, nearly 71% of the production value is generated in large farms, which is consistent with the fact that large farms occupy 76% of the rural territory. It is important to highlight the distribution of small farm land use: 45% of total small farm area is used for pasture, 22% for crops, and 24% is occupied by forests. Large farms display similar shares.

Cattle ranching and crop farming account for 78% of total production value from small farms. Figures 6.1a and 6.1b present the main products grown and raised in these economic activities for small and large farms, by region. The numbers are presented as a percentage of the sum of crop and cattle production values. In terms of crop production value, small farm production is concentrated in maize, cassava, soybean and coffee, which represent 33% of total cattle and crop production value. In addition, cattle ranching production represents 22% of this amount. The figures also show that, for small farms, dairy cattle is slightly more important than beef cattle, which is not the case for large farms, where beef cattle represents a much higher share of the rural production. Among Brazil's regions, the large share of cassava in the North and the large share of cattle and sugarcane in Center-West stand out. For large farms, it is important to highlight the large share of soybean in the South and in the Center-West, the large share of sugarcane in the Southeast, and the large share of beef cattle in the North.

Productivity Variation

The previous chapters discussed how agricultural productivity varies across regions in Brazil. Variation is even more substantial in small farming. Crop farm productivity is measured as gross value of crop production by hectare of farmed area. While gross value is an imperfect measure as it does not account for variations in the prices of inputs, data on net value is not available at this time. Cattle farm productivity is divided into two types: beef cattle farm productivity is measured by the number of heads per hectare, while dairy farms are evaluated by milk produced per cow.

Figure 6.2a shows the variation of crop farm productivity within each region and the variation across regions. A couple interesting points include: although the Southeast has the highest levels of crop farm productivity, and the most top-producing farms in Brazil, it also presents the largest variation within any region; the least productive municipalities in the South are more efficient than the least productive ones in all other regions. This is evidence that the South has been effective at guaranteeing a minimum level of knowledge and inputs for the majority of farmers.

Figures 6.2b and 6.2c present the corresponding results for cattle farm productivity. In this case, both heads per

[1] The official term for small holders is "family agriculture".

[2] A fiscal module is a unit of land measurement developed by the Brazilian government. It measures the minimum amount of land necessary for a farmer to achieve the subsistence level of income. It is expressed in hectares and changes by municipality, taking into account several factors: primary farm activity; income obtained from the prevalent economic activity; non-primary rural economic activities that are expressive in terms of income or area; and infrastructure available in and near the municipality. It varies from 5 to 110 hectares and is used to classify farms as small, medium or large.

Table 6.1: Economic Activity and Land Use, by Size

	All Farms	Small farms		Large farms	
		Quantity	Share of Total (%)	Quantity	Share of Total (%)
Employment (million)	16.57	12.32	74.38	4.25	25.62
Production value (billion BRL)	146.00	42.87	29.36	103.14	70.64
Number of farms (million)	5.18	4.37	84.36	0.81	15.64
Area (million ha)	333.68	80.10	24.01	253.58	75.99

Notes: The table presents number of workers, production value, number of farms and share of small and large farms. The definition of small farms follow the criteria presented in section 6.1. The first column presents statistics for all farms. The second and fourth colums present statistics for small and large farms, respectively. The second and fith columns present the statistics in the second and fourth columns as a fraction of those presented in the first colum, respectively. Source: 2006 Census of Agriculture - IBGE.

hectare and milk per cow are highest in the South, which also has the greatest levels of intra-regional variation. Both the least and the most productive municipalities in the region have higher yields than their counterparts in the rest of the country.

In sum, productivity variation is also relevant for small farms in Brazil. The next sections describe the relationship between productivity and some of its drivers discussed in the Introduction of this report: institutional factors; technology adoption; access to credit and insurance; and the infrastructure system.

6.2 Technology and Institutions

The last section showed that small farms have a high labor-to-land ratio. The quality of the labor is therefore of paramount importance to these farm's productivity. It is also an important precondition to successful technology adoption.

This section analyzes the adoption of technology and good farming practices by small farms. It first examines the technological drivers of small farm's productivity. **Fertilizers, mechanization and irrigation are important drivers of small-scale crop farming** while **lime usage and rotational grazing** are important for cattle farm productivity. These drivers are unevenly distributed across the country, which helps to explain the regional differences in productivity. This highlights the **potential that incentive programs have to improve farming practices by raising technology adoption levels**.

The section then moves to institutional factors, which can improve technology adoption and spread knowledge and good farming practices in at least three ways. First, **if a farmer does not have agricultural knowledge, he can use land rental markets to have a better qualified operator exploring his holding**. Productivity gains can then be split so as to benefit both the owner and the lessee. Second, **a farmer may obtain technical assistance and improve his practices**. Lastly, **higher educational levels increase farmers' overall ability to learn and implement better practices**. Evidence suggests that **while specialized training boosts crop farm productivity, cattle ranching only demands some level of formal education for good practices to spread**.

Overall, **education, well-functioning land rental markets and technical assistance are major drivers of productivity by spreading knowledge and good practices in agriculture**. Moreover, **these factors display significant variation across regions**, which helps explain differences in productivity levels across the country. This section assesses the relationship between such institutional factors and productivity in more detail.

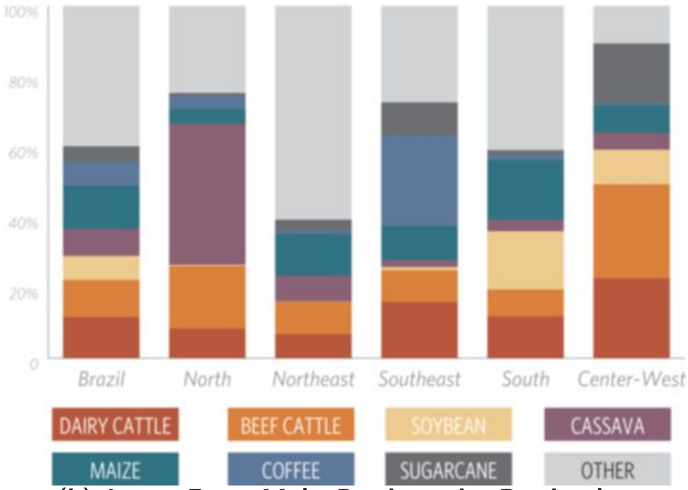
Technology

For each technological driver, the analysis splits municipalities into two groups: one "low-adoption" group and one "high-adoption" group, in such way that each group has the same number of municipalities. We then calculate and compare the average productivity in each group. Table 6.2 presents the findings.

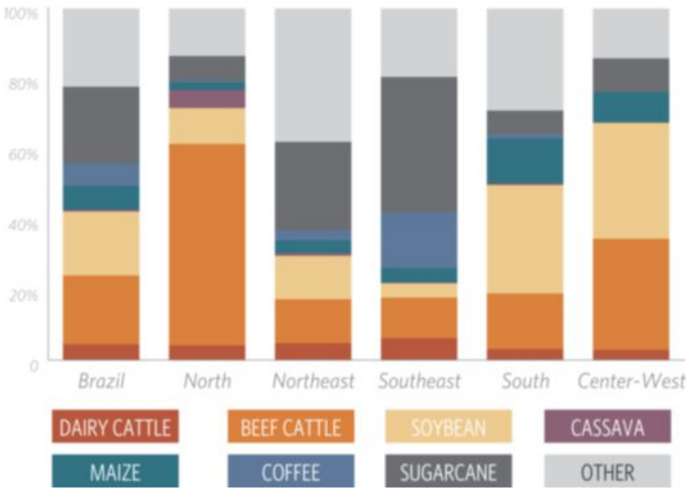
Crop productivity In municipalities with low usage of fertilizers, small farms average 2,280 BRL per hectare of cropland. This figure rises to 3,200 BRL per hectare in municipalities with above-average usage of fertilizers, a 40% increase. Table 6.2 reveals similar patterns for mechanical equipment (13%), irrigation (36%), and lime (59%), which is used to correct soil acidity.

Figure 6.1 Main Products by Region

(a) Small Farm Main Products by Production Value



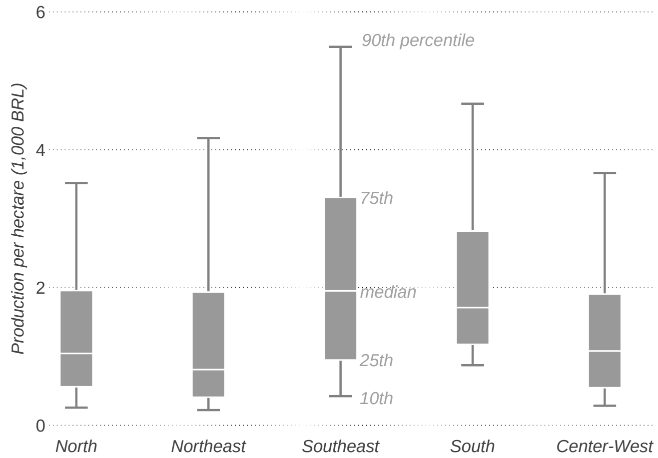
(b) Large Farm Main Products by Production Value



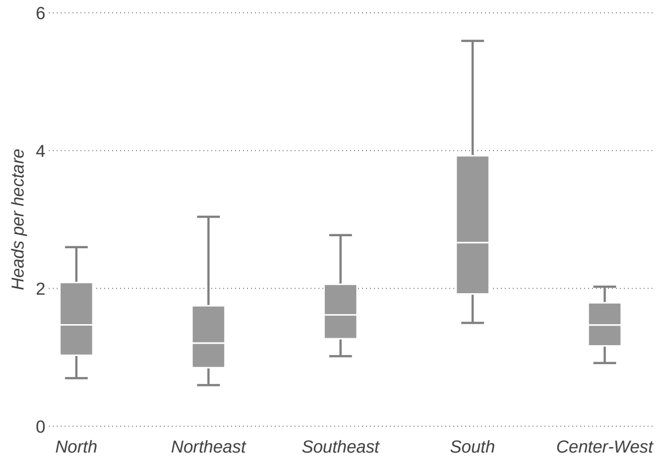
Notes: Share of production value for each type of activity as a percentage of total production value, by size (%). Source: 2006 Census of Agriculture - IBGE.

Figure 6.2 Variation in Productivity, by Region

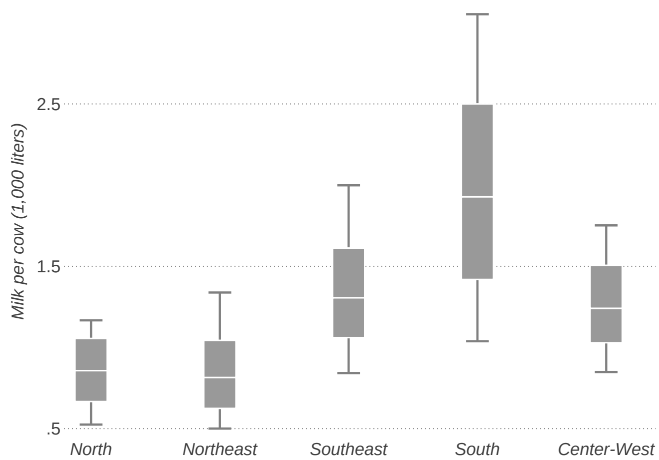
(a) Crop Farm Productivity



(b) Beef Cattle Farm Productivity



(c) Dairy Cattle Farm Productivity



The upper whishers show the 90th percentiles of municipalities' productivity; the upper box edges show the 75th percentiles; the white marks show the medians; the lower box edges show the 25th percentiles; and the lower whiskers show the 10th percentiles. Source: 2006 Census of Agriculture - IBGE.

Cattle productivity As for technological drivers of small cattle farm productivity, Table 6.2 shows that municipalities with above-average lime usage achieve 2.46 heads per hectare (HPH), while below-average municipalities achieve 1.91 HPH. Similar patterns are observed for mechanical equipment (13%), irrigation (36%), and lime (59%). Table 6.2 reveals similar patterns for small dairy farm productivity, as measured by milk per cow (MPC). Rotational grazing however has little effect on beef or dairy small farm productivity.

Given the importance of technological drivers of productivity, Table 6.3 examines how technology adoption varies across regions. It is clear that the productivity-enhancing factors identified in Table 6.2 are

Table 6.2: Productivity Drivers: Technology

	Average Productivity in Municipalities where Driver is...	
Driver	Low	High
Crop Productivity (BRL):		
Fertilizers	2.28	3.20
Mechanization	2.51	2.84
Irrigation	2.22	3.00
Lime usage	2.07	3.27
Heads Per Hectare:		
Lime usage	1.91	2.46
Rotational grazing	2.35	2.03
Milk Per Cow (liters):		
Lime usage	0.96	1.65
Rotational grazing	1.23	1.38

Notes: The table shows average productivity - crop production value per hectare (1,000 BRL), heads per hectare, and milk per cow (1,000 litters) - for municipalities below and above the median of the variable shown in the first column. All differences in mean are statistically significant at the 1% level.

concentrated in the regions with higher farm productivity: **the South has the highest rates of adoption of cattle farm technology**, and **the Southeast and the South have the largest adoption levels of crop farm technology.**

Table 6.3: Technology drivers (%)

	Lime usage	Fertilizers	Mechanization	Irrigation
Brazil	13.8	53.2	16.4	3.7
North	2.4	11.2	2.6	1.9
Northeast	2.1	29.3	9.9	2.9
Southeast	27.0	83.7	18.7	10.2
South	38.7	78.6	39.7	2.8
Center-West	13.2	35.9	9.9	4.6

Notes: Share of small farm area adopting fertilizers, mechanization, and using lime and irrigation. Source: 2006 Census of Agriculture - IBGE.

Institutions

Table 6.4 shows how small farm productivity responds to *land rental markets*, to the *presence of cooperatives*, to *technical assistance* and to *educational levels*. In the case of tenure structure, we classify municipalities according to the share of farming area where the producer is either a lessee or a partner to the owner. Therefore, municipalities "below the median" have a low share of rented area.

Land rental markets Table 6.4 shows that productivity is greater in municipalities where share of farms under rental is higher. This holds for both crop and cattle activities. In municipalities with a low share of farmland under rental, crop farm productivity is 2,050 BRL per hectare, whereas those above the median achieve 2,830 BRL per hectare. A similar pattern arises in the measures of cattle farm productivity: heads per hectare and quantity of milk per cow increase significantly. This suggests that landowners are leasing land to farmers with better knowledge of agricultural practices.

Technical assistance Table 6.4 shows how the availability of technical assistance affects productivity. Average crop production per hectare rises from 2,170 BRL in municipalities with limited assistance, to 3,190 BRL in those above the median — a difference of 47%. A similar effect is found for cattle: heads per hectare increase from 1.85 to 2.50 in the same comparison. Production of milk goes from 990 litters per cow to 1,630. These figures depict the critical role technical assistance plays. Accordingly, several public policies that target small farmers also provide technical assistance. Even so, the provision of technical assistance is still limited in Brazil: only 24% of small farms have access to it.

Cooperatives The role of cooperatives is not as clear-cut; crop farm productivity is lower in municipalities with high shares of farmers associated with cooperatives, while both measures of cattle farm productivity — heads per hectare and production of milk per cow — are higher. This is particularly important for milk producers, who often rely on cooperatives to stock and sell their output.

Education Finally, Table 6.4 considers the impact of three measures of education: the share of land where the farmer has at least (i) elementary, (ii) high school, and (iii) college education. The higher the level of education, the larger the impact on crop farm productivity. In the case of cattle farm productivity, in contrast, elementary education is most relevant, while high school and college play a lesser role. This evidence suggests that human capital and high specialization determine productivity

Table 6.4: Productivity Drivers: Institutional Features

	Crop Productivity (1,000 BRL)		Heads per Hectare		Milk per Cow (1,000 litters)	
	(1)	(2)	(3)	(4)	(5)	(6)
Driver	Low	High	Low	High	Low	High
Lease Area	2.05	2.83	1.85	2.48	1.11	1.46
Coops	2.80	2.56	2.07	2.26	1.20	1.43
Technical assistance	2.17	3.19	1.85	2.50	0.99	1.63
Elementary school	2.32	2.78	1.86	2.33	1.01	1.60
High School	2.09	3.02	2.05	2.14	1.17	1.45
College	2.10	3.00	2.20	1.99	1.23	1.38

Notes: Columns entitled Low present the average productivity – crop production value per hectare (BRL 1,000), heads per hectare, and milk per cow (1,000 litters) – in municipalities where the adoption of the driver is low. Columns entitled High present these averages in municipalities where adoption of the driver is high.

gains in crop farming, while in cattle ranching basic education and training are all that is required.

Table 6.5 shows the regional variation of the factors discussed above. Crop farm productivity is greater in the Southeast and in the South than in the other regions. Cattle ranching is significantly more productive in the South. Accordingly, the share of farmland under rental is much higher in these regions. Technical assistance, however, is highest in the South, much higher than in the Southeast. Educational levels display a similar pattern; however, college education is higher in the Southeast than in the South, which helps explain why crop farm productivity is higher in the former than in the latter region.

Overall, land tenure and technical assistance have important effects on crop farming, while cattle ranching is also affected by the presence of cooperatives. Education is important for both cattle and crop farm productivity, though only crop farm productivity seems to require higher level education.

Table 6.5: Institutional Features, by Region (%)

	Lease Area	Technical assis- tance	Elemen- tary school	College
Brazil	2.61	24.52	53.33	2.45
North	1.17	17.54	53.66	1.08
Northeast	1.87	11	35.62	1.44
Southeast	3.63	31.24	59.39	5.46
South	5.23	55.71	78.41	2.56
Center-West	2.36	25.18	63.03	3.7

Notes: Share of Small Farm area under rental, receiving technical assistance, and operated by a producer with elementary school and college. Source: 2006 Census of Agriculture - IBGE.

6.3 Financing and Risk

This section presents the main instruments of credit and insurance for small-scale farmers in Brazil, and discusses how they affect productivity. The availability of these instruments varies significantly across the country: **access to credit is much higher in the South than in other regions**. The impact on economic activity is unambiguous: **municipalities with more access to credit achieve higher average productivity for crop, cattle and dairy activities**. However, **a significant share of small-scale farmers pointed to the fear of indebtedness as the reason they did not seek credit in 2006**. This suggests that the insurance mechanisms to protect farmers from eventual output loss or price volatility have not been effective to deal with farming risks.

Public Credit Policies for Small-Scale Agriculture

This subsection describes the National Program for the Strengthening of Family Agriculture (*Programa Nacional de Fortalecimento da Agricultura Familiar*, Pronaf), the main credit policy targeted at small-scale farmers in Brazil. This program offers several lines of credit and finances both individual and collective agricultural projects, with the condition that they generate income to small producers of family farms and settlements of land reform. Interest rates are among the lowest in rural finance.

Pronaf was established in 1996 to replace the Program for the Enhancement of Small Rural Production (*Programa de Valorização da Pequena Produção Rural*, Provap), created in 1994 as a response to demonstrations of small-scale farmers. Pronaf allows for the provision of credit when the following conditions are met. First, the farmer must own an area no larger than four fiscal modules (six if the main economic activity is cattle ranching). Second, the farm must use mainly family labor. And third, the farmer must obtain at least 80% of his income from rural activity, and must live next to or at the farm. Lastly, the farmer's annual income must be below a threshold established each year by the government.[3]

Families eligible for Pronaf must use credit for expenses directly related to production and investment in machines, tools, and infrastructure. The beneficiaries of Pronaf are classified according to the farmer's gross annual income and to the volume of credit raised.[4] The program has four main instruments available to its beneficiaries: special credit lines, with subsidized interest rates and low collateral requirements; non-repayable grants to investments in infrastructure; technical assistance; and professional training.

Initially, Pronaf had only one credit line to fund agriculture operational expenses. In 1997, the program expanded to include farmers' investments, and farmers' and municipal expenditures with infrastructure, technical assistance and agricultural training. In 1999, the Agrarian Development Ministry, (*Ministério do Desenvolvimento Agrário*, MDA) became responsible for managing the program. MDA had been recently created and its objectives were to improve and develop small farms; manage land reform; and promote tenure regularization. In 2003, it created the Pronaf *Semi-Árido* to promote investments in water and sewage infrastructure in the semiarid regions of Brazil.

In 2004, the program gained new variants aimed at specific social segments: Pronaf 'Women' and Pronaf 'Young' (for farmers under 29 years old). In the same year, MDA established *Proagro Mais*, designed to help mitigate supply-side risks (loss of output due to natural phenomena). In 2006, the government gave direct subsidies for the production of cotton, rice, common bean, cassava, maize, soy bean and milk. Farmers were allowed to obtain credit for the production of castor bean, conditional on selling at least part of the output to the biofuel industry. the Price Guarantee Program for Family Agriculture (*Programa de Garantia de Preços para a Agricultura Familiar*, PGPAF) was created to help mitigate demand-side risks (Sá (2009)).

Other credit lines include Pronaf for Agribusiness, Pronaf Ecology, Pronaf More Food, and Pronaf Composition of Debt. Pronaf for Agribusiness provides credit to investments in the processing and marketing operations of agricultural activities, including extraction of forest products. Pronaf Ecology aims at environment-friendly activities such as nature and soil conservation, adoption of less polluting technologies, and cultivation of organic products. The program also offers specific lines of credit for operational expenses and for investment in the implementation, expansion and modernization of farm infrastructure.

Table 6.6 shows the importance of Pronaf and other credit programs to small farm rural production. In Brazil, 62.5% of total credit for small-scale agriculture comes from Pronaf and 20.2% from other credit programs. Only 17% of the total credit value is granted outside the credit programs scope. The Northeast and the North are highly dependent on Pronaf while the Southeast and the Center-West have other sources of credit. Table 6.6 also presents the distribution of financing to small-scale farmers by region. Variation is significant: the South region has the largest share of farmers with access to credit, and also the highest contracted value by hectare. The North region has both the smallest share and the lowest value per hectare. Overall, despite the importance of Pronaf and other public programs to small-scale agriculture, only 17% of small farms got credit in 2006. The next subsections discuss some of the barriers small farms face in obtaining credit, and the role of credit and insurance in small farming.

Table 6.6: Share of Small Farms Accessing Credit (%)

	Total	Pronaf	Other programs	No program
Brazil	17.68	62.56	20.23	17.21
North	8.95	66.42	22.29	11.29
Northeast	13.07	67.55	18.5	13.95
Southeast	14.71	51.78	26.17	22.05
South	36.96	65.45	18.35	16.21
Center-West	12.32	51.74	22.83	25.43

Notes: First column presents the share of small farms accessing credit. Second, third and last columns present the share of credit value that comes from Pronaf, other programs, and from no programs, respectively. Source: 2006 Census of Agriculture - IBGE.

Productivity and Credit

This section now analyzes the relationship between small farm productivity and credit. Table 6.7 reveals that

[3] For details, see Sá (2009).

[4] Additionally, there is one specific group composed by farmers in the Land Reform Program.

municipalities with low access to credit average 1.59 HPH; this figure rises to 2.68 HPH in municipalities with above-average access to credit, a 68% increase. Crop and dairy cattle farm productivity follow similar patterns. In sum, **access to credit is associated with higher productivity levels in small farms.**

However, **the lack of insurance mechanisms hinders the ability of farmers to raise credit**, since a large share of small-scale farmers do not seek loans due to fear of indebtedness.

Table 6.7: Productivity Drivers: Credit

	Average Productivity in Municipalities where Driver is...	
Driver	Low	High
Crop Productivity (BRL):		
Credit per hectare	2.24	2.95
Heads Per Hectare:		
Credit per hectare	1.59	2.68
Milk Per Cow (liters):		
Credit per hectare	1.00	1.61

Notes: The table shows average productivity - crop production value per hectare (1,000 BRL), heads per hectare, and milk per cow (1,000 litters) - for municipalities below and above the median of the variable credit per hectare in Brazilian reals. All differences in mean are statistically significant at the 1% level.

Table 6.8 presents the channels from which small farms obtain their credit. Banks are the main channel, supplying 84% of all credit to small farms. This is consistent with the evidence from the last section showing that most credit to small-scale agriculture is provided by Pronaf and other programs, since the major part of government credit programs is operated by public banks. To confirm this idea, the North and the Northeast, the regions with the highest shares of credit provided by Pronaf, are also the regions with higher shares of credit provided by banks.

Just as in the case of large-scale agriculture, the Center-West and the South are the regions that least depend on banks, with a non-negligible share of credit being provided by credit cooperatives in the South and by suppliers in the Center-West. However, in the case of small-scale agriculture, the share of credit provided by banks is above 75% for all regions; this is different from the large-scale agriculture case, in which only half of the credit in the Center-West is provided by banks, as shown in Chapter 5. These results show that other market mechanisms for raising credit are more important for large crop farms than for small farms in general.

There is also evidence that credit is more relevant for cattle ranching than for crop farms in large farms (see Assunção et al. (2013b)). Crop farms use their own resources, or obtain credit from other market mechanisms. These other mechanisms of credit are frequently misreported and may have been underestimated in the Agricultural Census.

Table 6.8: Rural Credit in Small Farms, by Source of Credit and by Region (%)

	Banks	Credit coops	Suppliers	Other
Brazil	84.14	7.24	1.5	7.12
North	95.1	2.75	0.24	1.91
Northeast	96.05	1.65	0.14	2.16
Southeast	89.11	7.22	0.64	3.02
South	77.62	9.87	1.76	10.75
Center-West	87.27	3.17	5.43	4.13

Notes: Share of credit value that is granted by each source. Source: 2006 Census of Agriculture - IBGE.

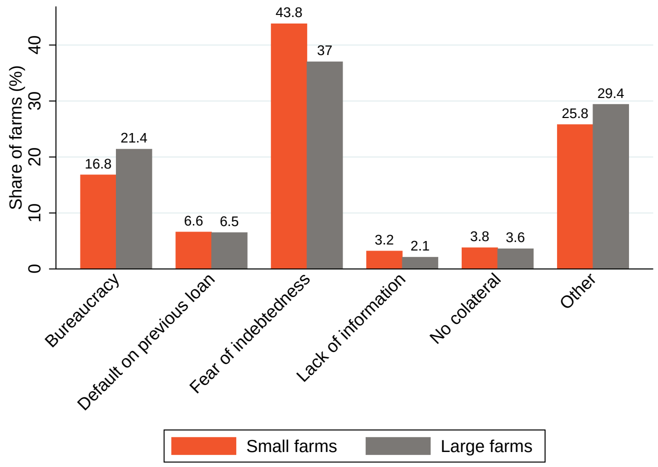
Figure 6.3 presents the main barriers to credit access. For small farms, the primary reason for not obtaining credit is the lack of necessity (52% of total). However, when examining only farms with the need for resources, the most relevant reason not to get credit stands out: nearly 44% of small farms who need credit do not raise it due to fear of indebtedness. In the case of large farms, this share is 37%. Bureaucracy accounts for more than 8% of the remaining cases. The fact that fear of indebtedness is such a relevant barrier is evidence that current policies to mitigate risk in the agricultural sector may not be fulfilling the needs of small farms.

In sum, smalls farmers' fear of indebtedness is an important obstacle for the expansion of credit in Brazil; insurance instruments could therefore increase access to credit, as small-scale farmers would be protected against shocks that otherwise would make them unable to repay loans. This section now presents some insurance mechanisms available to small-scale farmers.

Productivity and Insurance

Most government-provided insurance programs to support small-scale agriculture were created after 2006, which renders any analysis of their effectiveness in creating productivity gains unfeasible as the last comprehensive account of

Figure 6.3 Reasons for not Raising Credit



Notes: Share of small farms by reason for not raising credit as percentage of small farms that needed credit but did not raise it. Source: 2006 Census of Agriculture - IBGE.

Brazilian agriculture is the Agricultural Census of 2006. We now briefly discuss these programs.

Small-scale farmers are particularly exposed to risk: the lack of scale makes it difficult to diversify farming activities so as to cope with crop-specific hazards. Pronaf has different instruments to deal with such hazards. The Price Guarantee Program for Family Agriculture (*Programa de Garantia de Preços para a Agricultura Familiar*, PGPAF), created in 2006, reduces the exposure of small-scale farmers to price fluctuations: when sell prices fall below a threshold, defined by the federal government based on the cost of production in family farms, the program pays farmers a bonus up to 5,000 BRL a year. This payment corresponds to the difference between the guaranteed selling price of the product and its market price. By doing this, the PGPAF effectively works as a price insurance mechanism, with the ultimate objective of avoiding default by reducing borrowers' vulnerability to price fluctuations. Several products are eligible to PGPAF, including rice, common beans, maize, cassava, soy beans, coffee, wheat, oranges, and milk (Maia et al., 2011a).

Proagro Mais, created in 2004, is also an exclusive program to the beneficiaries of Pronaf.[5] It provides insurance against losses of crops, livestock or infrastructure due to adverse environmental conditions. To enroll in the program, farmers pay a subsidized premium to the federal government. Compensation may come as direct payments or as exemptions from financial obligations (Maia et al., 2011a).

Lastly, The Family Agricultural Insurance Program (*Seguro da Agricultura Familiar*, SEAF), created in 2006, is exclusive to small-scale farmers who have Pronaf credit for specific expenditures. It guarantees 65% of the predicted net income from the financed production.

Although these programs may help reduce small-scale farmers' exposure to risk, mitigation is still a concern. Figure 6.3 of Section 6.3 shows that the second main reason for not obtaining credit was fear of indebtedness. However, this picture does not capture the results of such programs as the Agricultural Census of 2006 has limited information on them. More data is necessary for a deeper analysis on risk-mitigation in small-scale farming.

6.4 Infrastructure

This section describes the infrastructure problems small farms face and their effect on both cattle and crop farm productivity. Two measures are used to capture the infrastructure available to the marketing of farm products. *Distance to state capitals* is a measure of transportation costs. The worse the road and transportation systems, the more expensive it is to reach consumer markets. *Distance to ports* has a similar effect and accounts for international markets. Both measures deliver the same message: **infrastructure is very important to explain productivity, and in-farm infrastructure is not enough to compensate for the lack of effective public systems**.

Table 6.9 shows how a greater distance to consumer markets hinders productivity. For municipalities where the distance to state capitals is above the median, the output value of small farms is 2,480 BRL per hectare, while those below the median produce 2,880 BRL per hectare — a difference of 16.0%. Results are similar for cattle farm productivity: both heads per hectare and dairy farm productivity are lower in municipalities far from consumer markets.

Table 6.9 shows the effect of storage capacity on yields. Productivity is higher in municipalities where in-farm storage capacity is high, although the effect is small. The reason for the small effect may be that other unaccounted-for factors affect farmers' decision to build capacity. Municipalities close to consumer markets, for example, probably have less need for in-farm storage

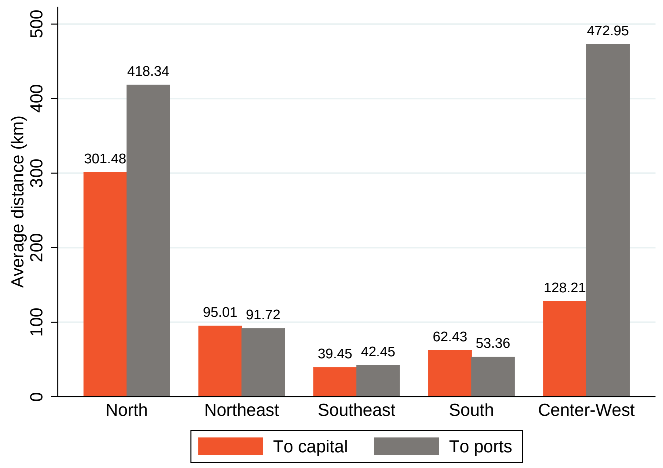
[5] The original Proagro is available for all farmers.

Table 6.9: Productivity Drivers: Infrastructure

	Average Productivity in Municipalities where Driver is...	
Driver	Low	High
Crop Productivity (BRL):		
Distance to capital	2.88	2.48
Distance to ports	2.83	2.51
Storage	2.53	2.55
Heads Per Hectare:		
Distance to capital	2.22	2.15
Distance to ports	2.34	2.04
Milk Per Cow (liters):		
Distance to capital	1.30	1.31
Distance to ports	1.35	1.27
Milk tank (%)	0.94	1.69

Notes: The table shows average productivity - crop production value per hectare (1,000 BRL), heads per hectare, and milk per cow (1,000 litters) - for municipalities below and above the median of the variable shown in the first column. All differences in mean are statistically significant at the 1% level.

Figure 6.4 Average Distance to Capital and Ports, by Region



Notes: The figure presents the average distance of all municipalities in each state to the respective state capital and to the nearest port. Source: 2006 Census of Agriculture - IBGE.

capacity, and these municipalities are generally the most productive ones. Chapter 5 showed that only 14% of the Brazilian storage capacity is within farms.

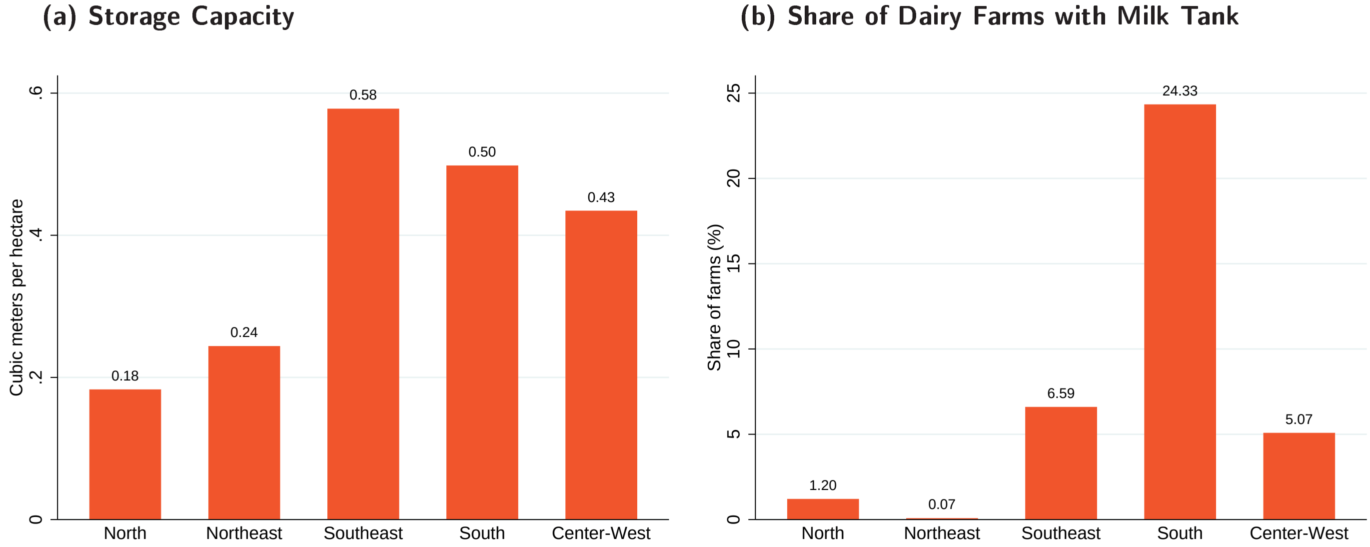
Storage is also important to dairy farm productivity. Table 6.9 shows that the availability of milk tanks is an important factor to increase the quantity of milk produced per cow. The presence of milk tanks is a signal of high milk quality, allowing producers to achieve higher prices. Therefore, they have more incentive to invest in cows and increase milk production per cow.

Figure 6.4 presents the average distance to the state capital and the average distance to ports for each region of the country. One can see that these distances are much greater in the North, the Center-West and Northeast than in the South and the Southeast. Infrastructure is particularly relevant for productivity when the distance to consumer markets is significant. As noted in Chapter 5, the transportation system in Brazil is not as effective as necessary to allow for profitable long-range marketing of products. Consequently, small farms are restricted to local markets when distances are significant.

Figures 6.5a and 6.5b describe, respectively, the share of farms equipped with milk tanks and the average grain storage capacity per hectare of production area. Milk and grain storage infrastructure in the North, the Northeast and the Center-West are also worse than in the South and the Southeast. It is impressive that in the South, 24% of milk-producing farmers have milk tanks. The second highest share, in the Southeast, is only 6%. It is not a surprise, then, that dairy farm productivity is much higher in the South than in other regions. In terms of grain storage capacity, the Southeast has the largest capacity, followed by the South. Again, not surprisingly, crop farm productivity is higher in these two regions than in the rest of the country.

In sum, the North, the Center-West and the Northeast regions suffer from a greater distance to consumer markets; moreover, the transport system is not sufficient to allow for long-range delivery. In fact, infrastructure is even worse in these regions.

Figure 6.5 Storage in Small Crop and Dairy Farms



Notes: Panel a presents grain storage capacity per hectare of harvested crop, by region. Panel b presents the share of dairy small farms with milk tank, by region. Source: 2006 Census of Agriculture - IBGE.

6.5 Policy Implications

This chapter has described small farm production and shown that productivity is highly associated with institutional factors, technology use, credit access, and infrastructure.

One important result of the chapter is that, although Pronaf is a large program of subsidized credit targeting small farms, a small share of small farms got credit in 2006 - the last year for which data was available. Additionally, for those farms that needed credit, the most common reason for not raising it was risk of default. This suggests there is scope to amplify public credit policies for small farms, and specifically improving insurance mechanisms that protect farmers against price shocks and other agricultural risks. While the Brazilian federal government has created some insurance programs linked to Pronaf in the last six years, it is not possible to assess their effectiveness at this time because of data availability issues.

This chapter also suggests that the public sector could provide technical assistance as a way to increase small farm productivity. Section 6.2 showed the great importance of technical assistance for small farm productivity. Although there is some technical assistance linked to the Pronaf, it seems to be insufficient to spread technology and knowledge and, consequently, to increase technology use in a way that will increase productivity.

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