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THE USE OF FINANCIAL TECHNOLOGY IN THE AGRICULTURE SECTOR

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Abstract

The finance sector has a key role to play in allowing agriculture to contribute to economic growth and poverty reduction. A rapidly evolving technological landscape is opening up new possibilities to target and price credit, to share risk, and to harness information technology to expand agricultural productivity. At the same time, many obstacles are not technological, so it is important to look for strategic places where policy and investment can help to improve outcomes for agricultural households. Our analysis first situates agricultural finance in the Asian context, and then discusses the role of financial technology (FinTech) in driving new products in credit and risk markets. We examine linkages to mobile money, financial literacy, national identification systems, and blockchain technology. The paper concludes with a discussion of policy takeaways for FinTech in agriculture to promote growth, enhance financial inclusion, and improve regional economic integration.

Keywords: financial technology, agriculture, credit, risk, financial literacy

JEL Classification: Q16, O16, O33

Contents

1. INTRODUCTION

Credit and risk are pivotal dimensions of agriculture everywhere in the world. Two core features of agricultural production are the long time lag between input investment and profit realization, and the large covariate risks imposed on agricultural production by weather shocks. These two dimensions create a set of interlocking problems both on the supply side (financial institutions face large and systemic risks in providing credit to agriculture) and on the demand side (farmers face many risks beyond their control in trying to finance the investments necessary to increase productivity). Fortunately, the technological landscape for the provision of financial services is shifting quickly, and the developing world appears poised to leapfrog legacy systems in a number of exciting ways. This paper summarizes recent advances in the technology that can be used to underwrite credit and risk in agriculture, places in context the gaps in coverage in Asia, and concludes with a set of policy recommendations as to the types of interventions that appear most promising across the highly varying national contexts of Asia.

The potential for digital financial services to increase growth in Asia, particularly among excluded segments of the population, is substantial. Financial technology (FinTech) is generating new ways to target and collateralize credit, to price and spread risk, and to organize agricultural value chains. A 2017 ADB report finds that digital payment systems could close 40% of the unmet need for payment services and 20% of the need for credit. The same report finds that widespread implementation of digital financial services could increase GDP growth in Indonesia and the Philippines by 2%–3% per year, and in Cambodia by as much as 6% (ADB and Oliver Wyman 2017). Indeed, worldwide we see that innovative financial technologies often take off precisely in economies that have certain enabling features but do *not* have well-developed legacy systems. Thus, microfinance has taken off in Indonesia and mobile banking in the Philippines, both of which have relatively poorly developed formal financial systems, and digital currencies dominate in the People's Republic of China (PRC) where low credit card penetration does not permit credit card use in online commerce. Therefore, FinTech represents a space where innovation can be made to serve the marginalized in ways that generate both welfare and economic growth.

Information and communication technology is changing agriculture in many dimensions beyond financial services. Clearly, global access to mobile phones is fundamentally changing the way that farmers access price information, search for buyers, and build brands as they attempt to move up the value chain. That said, a large number of rigorous studies conducted on the use of specific technology platforms to transmit price information or to conduct agricultural extension have arrived at surprisingly mixed results. Recent innovations in risk sharing, such as the use of index insurance, have largely fallen flat due to lack of demand. Some of the excitement around novel FinTech solutions for agriculture, such as the use of the blockchain, is still largely unproven. Hence, in this paper we also provide a summary of the recent rigorous empirical evidence from field studies as to the success of FinTech innovations, and try to point the way forward for the most promising financial technologies.

The centrality of credit and risk may be clearest when we consider agriculture as a part of the overall economy, and consider the central role played by farming in the broader Agricultural Transformation and the subsequent Structural Transformation. Most developing economies begin with a very large share of the population engaged in smallholder agriculture, farming small plots with low capital intensity and trading little of their output. To become a direct contributor to economic growth, agriculture must

become more capital intensive so as to allow it to bolster exports and contribute to overall productivity. This process requires heavy investments to be made in the farming sector which will in general amplify the financial risks faced by farming households. To permit these investments to be made, then, we must consider both the access to finance enjoyed by agricultural households and the tools at their disposal to control the risks they face in making production more capital intensive. Agricultural land itself is the most important store of value that can be used to collateralize this investment, which creates an integral tie between land ownership rights and the apportionment of default risk in agriculture. FinTech is being used both to enhance the ability of farmers to use collateral and to permit new forms of more flexible, uncollateralized credit.

What is the particular role played by agriculture that makes it a sector of unique interest in terms of economic development? Two particularly important and quite distinct motivations are apparent. The first is its “macro” role in the AT/ST: in order to liberate the labor that drives urbanization and industrialization, agriculture must engage in a set of labor-saving investments that boost overall productivity. For poorer countries, the development of agricultural processing and export businesses typically represents a critical step on the path toward a modern economy. The second is its “micro” role as the sector in which the large majority of the low-income population works, meaning that aggregate poverty and inequality are likely to be driven strongly by changes to the nature of agricultural production, particularly at low levels of overall development.

Both the “macro” and “micro” roles of agricultural development are served when a country undergoes a successful structural transformation over the long term, but when we seek to adjust agricultural policy at a moment in time, the levers for these two purposes may be quite distinct. To promote agriculture’s role as a sector in the overall economy, policy should be focused on improving value added, export markets, labor productivity, diversification, and the transmission of labor toward more productive sectors. For these purposes, FinTech needs to drive mechanization and processing capacity, as well as manage a complex set of risks that accompany engaging with the world market (quality certification, handling exposure to global commodity price fluctuation, external demand shocks). If instead we focus on the critical micro-level welfare implications of agriculture as a sector employing most of the population below the poverty line, quite a different set of objectives may emerge, particularly in the short term. Here, we may see smallholder farming more as a necessary reality to be confronted, and hence interventions that generate marginal improvements in risk-adjusted profits for households can have substantial welfare consequences, even in the absence of any macro-level transformation. Indeed, GDP growth emanating from agriculture has three times the effect on increasing the income of the bottom 40% of the distribution as growth emanating from other sectors (de Janvry and Sadoulet 2009). In focusing on agriculture’s pro-poor dimension, the policy focus will tend toward micro-credit and micro-insurance, as well as interventions that can target and expand access to financial services for previously marginalized groups. To use the language of Dorward et al. (2009), the macro policies involve “stepping up” and “moving out” of agriculture while the micro-level policies help farmers to “hang on” as smallholders.

In certain dimensions, these two objectives face common obstacles, so we can achieve win-wins: both agendas can be promoted by improving agricultural productivity, shifting weather and global price risks off of farmers, and enhancing household-level income diversification. In other dimensions, they may be at odds: transfers in the form of subsidies to prices, interest rates, or the cost of agricultural risk may enhance welfare in the short term yet retard the movement toward the consolidation of land and movement of labor that is typically associated with economic development at the national level. FinTech appears to be a particularly attractive approach to agriculture when seen in this

light because it embeds a strong logic for the win-win propositions of better targeting of credit, better pricing of risk, and a shift of aggregate risk to better diversified parties. All these changes should be beneficial to both macroeconomic efficiency and the welfare of smallholder farmers.

FinTech plays a number of critical roles in driving the ability to provide mass-scale agricultural finance, particularly in developing countries where access may be far from universal. The array of digital technologies has dramatically decreased the cost of providing services on the margin, allowing them to be offered in smaller packages to poorer customers. This holds out the promise that less developed countries and remote regions could leapfrog legacy systems and use mobile/digital technology to drive agricultural productivity in novel ways. Big data tools allow institutions to target credit more precisely, thereby reaching better borrower pools and expanding access to uncollateralized credit. Better measurement of climate shocks using various types of remote sensing permit a shifting of covariate risk within the agricultural system (although progress has been slower here than with credit).

This paper provides an overview of the use of FinTech for agriculture. We begin our analysis by providing context for levels of financial penetration, agricultural productivity, and stages in the agricultural transformation globally and within Asia. We then move to a detailed discussion of credit products, and the way in which novel technologies can target and extend uncollateralized credit in new ways, can allow new types of assets to serve as collateral, and allow for an expansion of agricultural productivity. We then move to the use of FinTech to tackle risk in agriculture, focusing on the weather index insurance products that have been extensively piloted over the past decade. Following that, we discuss three specific forms of FinTech that are critical enablers of changes to the operation of agricultural supply chains—mobile money, biometric identification, and the blockchain—as well as the role financial literacy plays in generating financial inclusion. We conclude with a set of policies and products that seem to have particularly strong theoretical or empirical justification, and the ways in which the context and policy objectives alter the critical areas of focus.

2. THE CONTEXT

Seen from a macroeconomic context, agriculture is playing a declining role in production and employment in ADB members. From 2000 to 2016, employment in agriculture among the ADB members fell from 46% to 30%, and the contribution of agriculture to total value added declined from 21% to 12.7% (Table 1). In 1990, the population of ADB members was 70% rural and only 30% urban, while by 2017 the share living in rural and urban areas had equalized (Figure 1). In keeping with an agricultural transformation that is well underway, these changes were accompanied by a large increase in agricultural productivity, with cereal yields per hectare increasing on average from 2,848 kg in 2000 to 3,637 kg in 2016, an improvement of 28% in only 16 years. Figure 2 shows the evolution of cereal yields over this interval by country, demonstrating particularly impressive improvements in the PRC and Indonesia.

In aggregate, then, Asia is clearly seeing the mass-scale movement of population out of rural areas and the mechanization of agriculture that is critical to a structural transformation in the process of overall economic development. However, workhorse theoretical models such as the Lewis model have suggested for decades that increases in the welfare of urban workers will ultimately be limited by the level of immiseration in the rural areas, and therefore finding the policy and financial tools to allow for an increase in wages and productivity in agriculture are key to allowing economic development to

benefit workers. Improving the flow of agricultural financing and technology is critical in allowing countries to escape a low value-added poverty trap (Manova and Yu 2013), even as the region as a whole moves away from agriculture.

Table 1: The Role of Agriculture in ADB Members, 2000–2016
(% of Total Value Added,[a] % of Total Employment,[b c] % of Total Exports,[d] Kg/Hectare[e f])

	% of Value Added from Agriculture[a]		Employment Share in Agriculture[b]		Employment Share in Industry[c]	
ADB Members	**2000**	**2016**	**2000**	**2016**	**2000**	**2016**
Afghanistan	33.75	20.97	76.83	61.77	5.50	6.72
Armenia	27.11	15.66	46.80	34.20	16.92	15.91
Australia	3.20	2.60	4.55	2.61	21.56	19.28
Azerbaijan	16.73	5.62	41.83	36.87	11.45	14.23
Bangladesh	21.99	13.73	59.92	40.10	11.66	20.96
Cambodia	37.75	24.06	74.48	27.07	7.56	27.03
PRC	15.36	8.35	43.40	18.07	28.66	26.73
Georgia	24.95	7.38	53.01	41.08	9.40	12.43
Hong Kong, China	0.08	0.08	0.31	0.22	20.56	13.12
India	22.01	15.87	59.66	43.09	16.56	23.75
Indonesia	16.20	13.31	44.06	31.50	18.10	21.72
Japan	1.47	1.15	5.05	3.50	31.15	25.60
Kazakhstan	9.14	4.49	36.76	17.97	15.87	20.79
Korea, Rep. of	3.96	1.94	10.16	4.90	28.90	24.84
Kyrgyz Republic	35.84	12.58	48.82	26.74	13.24	22.13
Lao PDR	35.77	16.72	82.47	61.67	4.06	9.60
Mongolia	26.82	11.05	51.37	30.39	11.61	19.01
Myanmar	52.38	25.82	74.86	50.61	10.67	16.45
Nepal	36.92	28.10	75.79	72.01	7.13	7.95
New Zealand	7.31		8.66	6.57	23.46	20.20
Pakistan	22.96	23.05	45.41	42.14	18.95	23.66
Papua New Guinea	34.91		66.52	20.63	4.38	7.50
Philippines	15.46	9.66	38.51	26.47	16.07	17.60
Sri Lanka	18.31	7.59	38.40	27.10	24.62	25.55
Tajikistan	26.46	20.38	59.98	51.18	16.36	16.47
Thailand	9.10	8.58	47.55	33.05	19.79	22.66
Timor-Leste	7.37	11.35	60.40	24.89	7.85	14.66
Turkmenistan	20.15		22.81	8.34	38.68	44.95
Uzbekistan	27.69	16.72	38.01	21.93	31.20	37.61
Viet Nam	24.22	15.83	63.56	41.37	13.73	24.92
Unweighted Average:	21.18	12.69	46.00	30.27	16.86	20.13

continued on next page

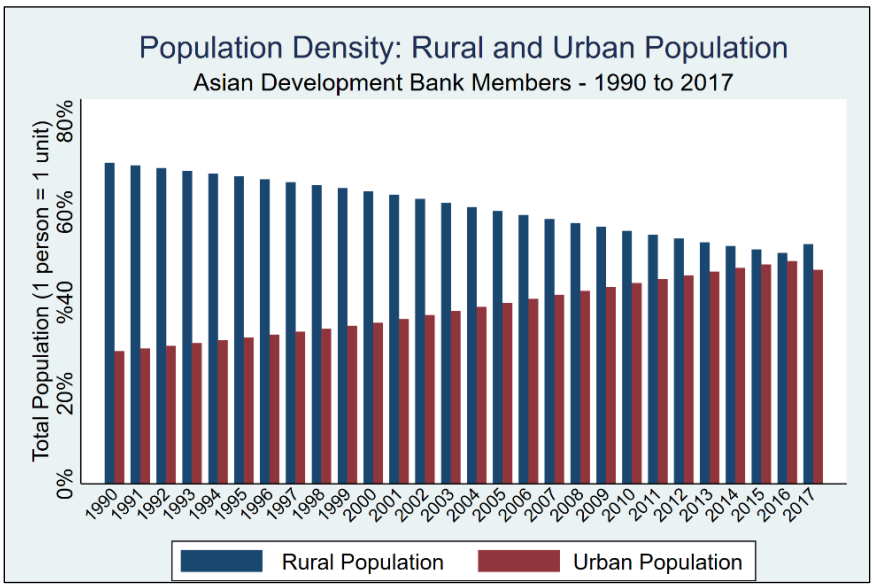
Table 1 *continued*

ADB Members	Export Share in Agriculture[d] 2000	Export Share in Agriculture[d] 2016	Fertilizer Use[e] 2000	Fertilizer Use[e] 2016	Cereal Yields[f] 2000	Cereal Yields[f] 2016
Afghanistan		16.36	3.86		1,318.83	1,981.70
Armenia	3.27	0.59	27.97		1,809.08	3,076.10
Australia	6.04	2.86	47.39		1,909.33	2,074.30
Azerbaijan	4.43	0.28	10.85		2,162.83	3,004.70
Bangladesh	1.65		179.33		3,149.29	4,628.90
Cambodia	2.15	2.08	5.79		1,990.36	3,459.90
PRC	1.03	0.42	402.14		4,906.07	6,029.20
Georgia	2.86	1.25	33.04		1,994.86	2,517.20
Hong Kong, China	0.37	2.95	461.20		2,000.00	2,000.00
India	1.45	1.27	112.10		2,286.27	2,992.80
Indonesia	4.72	5.07	132.57		4,053.31	5,405.50
Japan	0.52	0.75	342.59		6,002.18	4,975.50
Kazakhstan	1.74	0.30	1.23		937.18	1,347.70
Korea, Rep. of	1.00	0.89	512.42		6,226.77	6,795.20
Kyrgyz Republic	13.06	3.30	19.52		2,515.39	3,104.40
Lao PDR		3.24			2,966.76	4,626.70
Mongolia	21.81	6.93	6.30		682.78	1,279.40
Myanmar		2.60	10.26		3,041.03	3,607.40
Nepal	0.73	3.55	8.33		2,096.52	2,605.40
New Zealand	13.91	12.25	2,148.70		6,360.53	8,383.80
Pakistan	2.44	0.91	108.18		2,256.48	3,064.20
Papua New Guinea	4.90		175.22		3,792.42	4,737.80
Philippines	0.71	0.76	157.78		2,591.38	3,529.00
Sri Lanka	1.87	2.65	276.51		3,298.01	3,897.40
Tajikistan	12.59		35.88		1,523.00	3,348.70
Thailand	4.10	3.87	126.03		2,747.82	3,031.80
Timor-Leste	0.13				1,541.90	2,454.40
Turkmenistan	16.79				2,192.81	1,075.60
Uzbekistan					2,946.42	4,613.10
Viet Nam	2.21	1.41	335.86		4,135.12	5,448.00
Unweighted Average:	4.86	3.19	218.50		2,847.82	3,636.53

ADB members with population over 1 million.

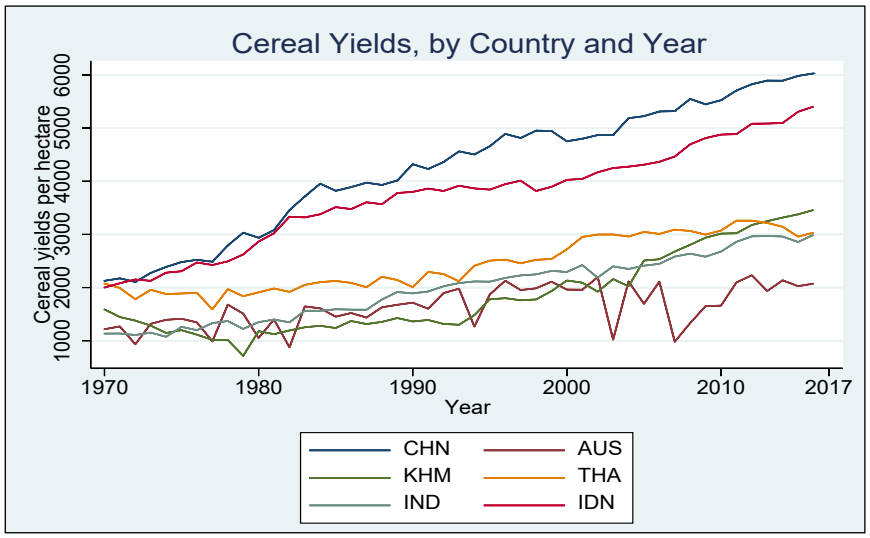
Source: World Development Indicators Database 2018.

Figure 1: Evolution of Rural/Urban Population



Source: World Indicators 2018.

Figure 2: Cereal Yields (kg per hectare for wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains) **by Country and Year**



Source: FAO Stat.

Further, this picture of a strong aggregate decline in the importance of agriculture masks an enormous degree of cross-country differentiation. Indeed, in this respect, Asia is the most heterogeneous area of the world. This can be seen in the difference between the development level of countries like Japan and the Republic of Korea, which together account for almost 6% of the world gross domestic product (GDP), and that of Myanmar and Nepal, which combined do not represent 0.40% of the world's GDP (World Development Indicators Database 2018). Even in the most recent data, countries such as Afghanistan, the Lao People's Democratic Republic (Lao PDR), and Nepal still have more than 60% of their population engaged in agriculture, while this fraction is below 5% for Australia; Hong Kong, China; and Japan. Given the importance of export markets as

a vehicle for value added in agriculture, this diversity in development levels within Asia should be seen as an opportunity for less developed countries in the region to exploit the purchasing power of their wealthier neighbors to their own benefit. Also, agriculture can continue to play an important role in the economies of even very developed economies, as witnessed by the fact that the farming sector represented 12.25% of New Zealand's exports in 2016, second only to Afghanistan within Asia.

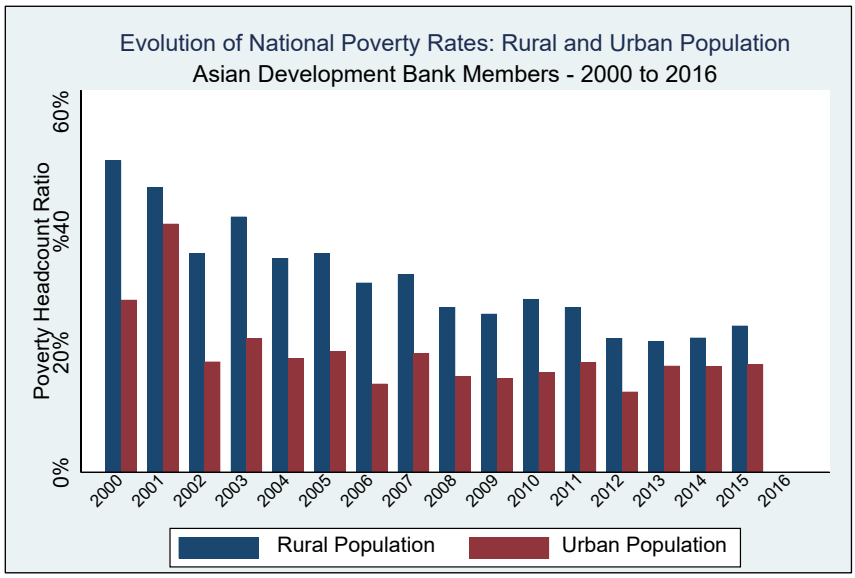
Table 2: Changes in Welfare, 2000–2017
(Purchasing Power Parity,[a] Kcal/day[b])

	GDP Per Capita[a]		% of Population Rural		Food Deficit[b]	
ADB Members	1995–2005	2016–2017	1995–2005	2016–2017	1995–2005	2016–2017
Afghanistan	1,090	1,803	78.70	72.65	311.45	173.00
Armenia	3,308	8,489	35.14	37.49	143.09	41.00
Australia	34,828	44,571	12.89	10.38		
Azerbaijan	4,820	15,924	48.23	44.96	144.00	12.00
Bangladesh	1,651	3,422	76.09	64.59	196.00	116.00
Cambodia	1,413	3,555	81.53	78.94	201.55	97.00
PRC	3,875	14,703	63.70	42.85	138.36	74.00
Georgia	3,446	9,511	47.15	46.07	176.82	55.00
Hong Kong, China	34,414	55,234	0.00	0.00		
India	2,520	6,261	72.21	66.66	135.09	109.00
Indonesia	6,163	10,978	58.56	45.18	118.00	51.00
Japan	33,847	38,642	19.50	5.88		
Kazakhstan	11,016	23,751	44.45	46.77	26.64	18.00
Korea, Rep. of	20,755	35,479	20.26	17.35	12.09	4.00
Kyrgyz Republic	2,072	3,352	64.48	64.07	103.09	40.00
Lao PDR	2,516	6,235	77.86	59.84	297.36	128.00
Mongolia	4,860	11,601	41.59	26.80	324.18	156.00
Myanmar	1,415	5,448	72.93	65.07	429.18	103.00
Nepal	1,519	2,370	86.76	80.81	153.55	51.00
New Zealand	27,938	35,931	14.29	13.66		
Pakistan	3,539	4,946	66.79	60.54	168.64	172.00
Papua New Guinea	2,844	3,820	86.59	86.94		
Philippines	4,288	7,416	52.32	55.74	151.82	93.00
Sri Lanka	5,391	11,557	81.56	81.56	261.00	192.00
Tajikistan	1,295	2,830	72.94	73.05	260.82	250.00
Thailand	9,802	15,992	67.31	47.89	163.82	53.00
Timor-Leste	6,294	6,934	73.69	66.29	227.00	184.00
Turkmenistan	5,216	16,019	54.08	49.42	56.00	22.00
Uzbekistan	2,548	6,146	62.55	63.45	66.36	29.00
Viet Nam	2,615	6,005	75.47	65.44	218.73	83.00
Unweighted average:	8,243	13,964	56.99	51.34	179.39	92.24

ADB member countries with population over 1 million.
Source: World Development Indicators Database 2018.

The deep structural changes to Asian economies have been accompanied by a very dramatic reduction in poverty. Table 2 shows that average GDP per capita among larger ADB members has risen from just over $8,000 to almost $14,000 in purchasing power parity terms during the 18 years from 2000 to 2017, and over the same interval the average food deficit fell from 180 to 92 kilocalories per person per day. This halving of nutritional shortfalls over such a short period is impressive, and given the large decreases in the share of the population in rural areas over the same period might be thought to have resulted from urbanization. However, Figure 3, which plots the declines in poverty rates at the national level over the same period, tells quite a different story. It shows that subsequent to 2002 almost all of the reduction of aggregate poverty that has taken place in Asia has done so in rural areas, emphasizing the critical role that the agriculture sector plays in employing the poor. In this sense, while agriculture may play a declining role in overall macroeconomic importance over time, it is the sector in which growth has the strongest role in reducing poverty (de Janvry and Sadoulet 2009).

Figure 3: Evolution of National Poverty Rates, ADB Members



Source: World Development Indicators, 2018.

Clearly, access to financial services will play a critical role in enhancing agricultural productivity and thereby generating the benefit from its poverty-reducing abilities. In this regard as well, we see both tremendous growth in Asia over recent decades and a great deal of heterogeneity remaining at the present moment. From 2000 to 2017, overall credit to the private sector rose from 42.5% to 62.8%, the number of bank branches per 100,000 people rose from 13 to 16.5, and the number of depositors per 1,000 adults rose from 1,350 to 1,550. Perhaps most impressive, there was a reduction of more than one-third in the average interest reported in the WDI, from an APR of 15.4% to just over 10%. In general, there has been a very meaningful improvement in overall financial depth over this period. Again, however, this masks enormous heterogeneity. Afghanistan, Kazakhstan, the Lao PDR, Myanmar, and Viet Nam each have fewer than five bank branches per 100,000 people, while Georgia, Japan, Mongolia, and Uzbekistan each have more than 30.

Table 3: Financial Depth

ADB Members	Credit to the Private Sector, % of GDP		Bank Branches per 100,000 pop		Depositors with Commercial Banks (per 1,000 adults)		Interest Rates	
	1995–2005	2016–2017	1995–2005	2016–2017	1995–2005	2016–2017	1995–2005	2016–2017
Afghanistan		3.42	0.48	2.22		188.98		15.00
Armenia	7.24	47.52	11.57	23.10	289.91	1,567.77	34.48	15.88
Australia	87.29	141.71	30.65	27.80			7.50	5.33
Azerbaijan	4.85	21.40	6.64			2,021.38	17.77	16.46
Bangladesh	23.13	46.25	6.89	8.44	345.99	724.90	12.66	9.97
Cambodia	6.31	83.97						
PRC	107.05	156.47		8.78		34.04	6.95	4.35
Georgia	7.26	57.68	10.21	32.67	324.18	1,867.42	21.13	12.05
Hong Kong, China	152.19	203.80	23.40	21.43			7.43	5.00
India	29.09	49.55	8.95	14.06	607.31	1,731.27	12.80	9.59
Indonesia	33.80	32.77	5.22	17.39	497.12	1,055.58	20.07	11.48
Japan	144.68	102.98	34.50	34.10	7,907.62	7,190.45	2.21	1.04
Kazakhstan	14.60	28.33	3.84	2.96				
Korea, Rep. of	83.00	143.88	17.07	16.26	4,121.82	5,212.49	8.59	3.42
Kyrgyz Republic	6.05	20.75	5.22	8.38			44.73	22.18
Lao PDR	8.09			3.04		579.16		
Mongolia	12.89	52.24	40.83	70.37	324.79	1,333.64	35.40	19.87
Myanmar	8.15	22.72	1.78	3.41	114.42	251.84	15.67	13.00
Nepal	26.17	80.92	2.56	9.58		657.04	10.81	
New Zealand	104.49		35.08					
Pakistan	24.72	16.69	7.71	10.36	163.55	380.10	8.16	8.48
Papua New Guinea	15.69	17.19	1.83				14.29	8.76
Philippines	38.95	46.24	8.11	8.87	364.95	577.09	12.41	5.63
Sri Lanka	30.43	45.56	8.93				10.94	10.49
Tajikistan	10.76	15.10	4.96				12.49	
Thailand	119.17	112.56	8.01	12.37	1,144.14	1,549.30	10.10	4.44
Timor-Leste	5.84	8.37	2.11	5.04				13.67
Turkmenistan								
Uzbekistan			39.58	36.14				
Viet Nam	35.51	127.24		3.87		963.38	12.09	7.18
Unweighted average:	42.50	64.82	13.04	16.55	1,350.48	1,549.21	15.39	10.15

ADB member countries with population over 1 million.

Source: World Development Indicators Database 2018.

What, then, are the levers that can be used to enhance financial access? FinTech services can play a crucial role here. Table 4 shows summary statistics for three important underlying institutions that enable financial deepening, namely credit bureaus, asset registries, and access to mobile services. In the period 1995–2005, only four ADB members had meaningful credit bureau coverage (Australia; Hong Kong, China; the Republic of Korea; and New Zealand), and none of them had credit registry coverage for more than 5% of the population. By 2016–2017, this picture had changed substantially; the number of countries in which more than half the population was covered by credit bureaus had more than doubled, and credit registries had become more widespread. Australia; Hong Kong, China; Japan; the Republic of Korea; and New Zealand all report universal coverage by credit bureaus in the most recent data. As indicated in Figure 4,

credit bureau coverage is highly correlated with the overall level of economic development of a country. Interestingly, credit registries have taken off in a set of less developed economies (members with more than 40% coverage are the PRC, Indonesia, Mongolia, and Viet Nam), suggesting that the development of credit registries has been driven more by policy than emerging as a natural feature of overall economic development. As might be expected, mobile phone coverage has skyrocketed during this period, with the number of mobile subscriptions rising more than tenfold, from 12 per 100 people to 114.7. More than half of the countries in the region have more than one mobile phone subscription per adult, and the lowest rate of penetration, in Papua New Guinea, still indicates that nearly half of all adults have mobile phones.

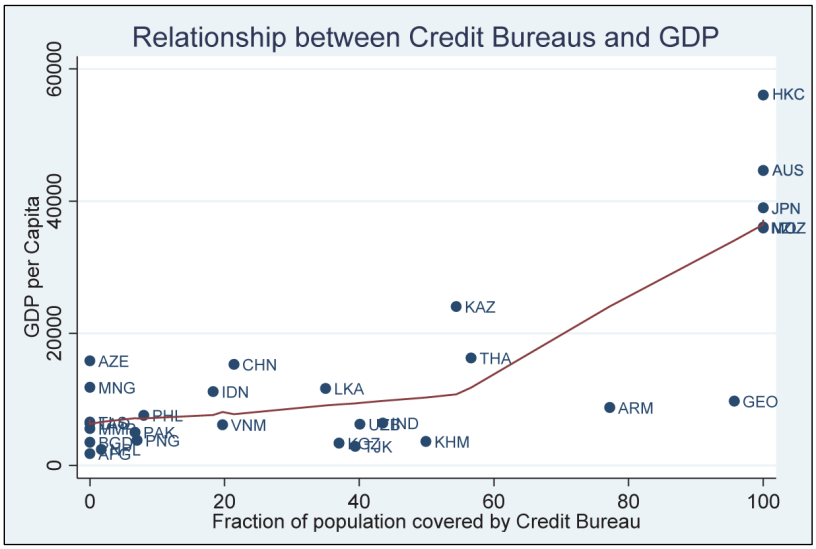
Table 4: Presence of Financial Infrastructure

	Private Credit Bureau Coverage (percent of population)		**Public Credit Registry Coverage** (percent of population)		**Mobile Subscriptions** (number of subscriptions per 100 people)	
ADB Members	**1995–2005**	**2016–2017**	**1995–2005**	**2016–2017**	**1995–2005**	**2016–2017**
Afghanistan	0.0	0.0	0.0	0.9	0.75	62.34
Armenia	0.0	74.2	1.3	0.0	2.33	117.43
Australia	97.7	100.0	0.0	0.0	48.46	110.05
Azerbaijan	0.0	0.0	0.2	37.0	7.82	104.77
Bangladesh		0.0		0.9	0.98	83.45
Cambodia	0.0	47.0	0.0	0.0	2.39	126.35
PRC		21.3		92.5	10.62	97.25
Georgia	0.0	92.2	0.0	0.0	7.86	140.95
Hong Kong, China	63.0	100.0	0.0	0.0	72.77	240.80
India		32.5		0.0	1.65	85.17
Indonesia		9.2		53.6	5.02	147.66
Japan		100.0		0.0	48.28	130.61
Kazakhstan	0.0	53.2	0.0	0.0	6.55	141.96
Korea, Rep. of	80.7	100.0	0.0	0.0	46.73	120.68
Kyrgyz Republic	0.1	33.8	0.0	0.0	1.87	127.84
Lao PDR	0.0	0.0	0.0	11.1	1.76	58.57
Mongolia	0.0	0.0	3.5	43.6	7.04	111.24
Myanmar		0.0		0.0	0.08	95.65
Nepal	0.1	1.8	0.0	0.0	0.17	110.83
New Zealand	96.8	100.0	0.0	0.0	43.65	124.44
Pakistan		6.3		9.7	1.43	70.65
Papua New Guinea	0.0	6.6	0.0	0.0	0.29	46.78
Philippines	3.6	9.1	0.0	0.0	14.43	109.37
Sri Lanka	2.1	46.1	0.0	0.0	4.56	124.03
Tajikistan	0.0	37.6	0.0	0.0	0.62	107.61
Thailand	16.7	54.8	0.0	0.0	16.48	173.78
Timor-Leste	0.0	0.0	0.0	5.6	3.22	117.61
Turkmenistan					0.38	151.43
Uzbekistan	0.0	34.0	0.0	0.0	0.72	73.98
Viet Nam	0.0	17.3	1.0	46.4	2.41	127.53
Unweighted average:	16.4	37.1	0.3	10.4	12.04	114.69

ADB member countries with population over 1 million.

Source: World Development Indicators Database 2018.

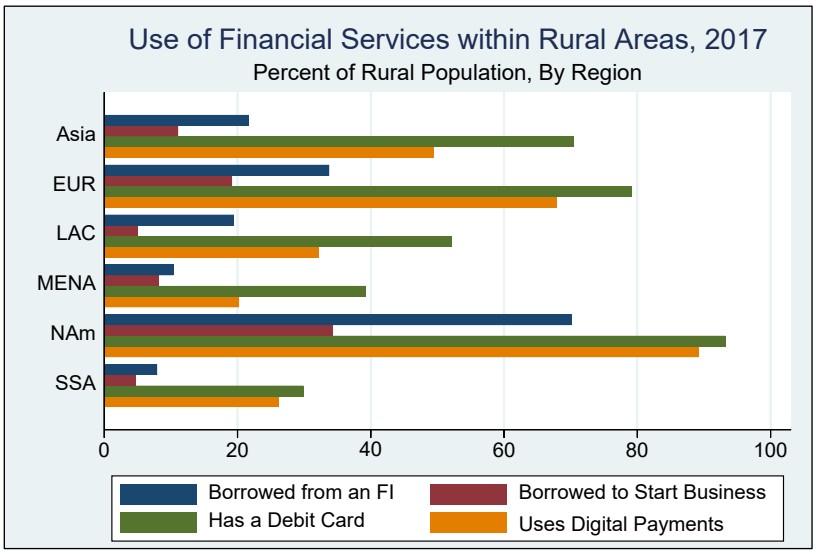
Figure 4: Credit Bureau Coverage and GDP, 2017



Source: WDI.

How important are financial services in promoting the growth of agriculture in Asia? To get a picture of this, we must move to more specialized data. Information from the World Bank's Global Financial Inclusion Database (FinDex) database allows us to disaggregate the use of financial services only in rural areas. Figure 5 shows that Asia and the Pacific overall has similar credit depth in rural areas as Latin America and the Caribbean (LAC) (about 20% of the rural population have loans from a financial institution), that over 70% of the rural population is banked in having access to a debit card, and roughly half of the rural population uses digital payments, but that only just over 10% of the rural population has taken a loan to start a business. In general, Asia and the Pacific shows rates of rural financial penetration that are between those of the developed world (North America and Europe) and the developing world (Latin America and the Caribbean, Middle East and North Africa, and Sub-Saharan Africa).

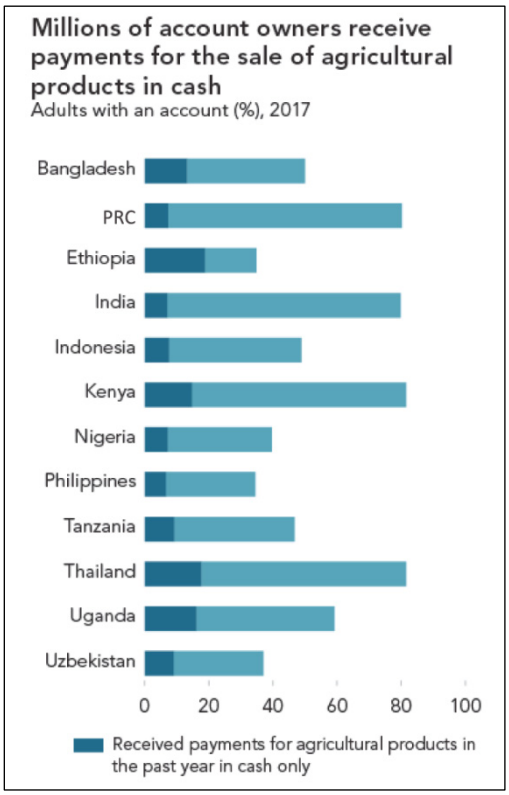
Figure 5: Use of Financial Services in Rural Areas



Source: FinDex/WDI.

We conclude the overview of context by suggesting that huge possibilities exist for financial development to push agricultural development in Asia. Data from FinDex show that the largest concentrations of unbanked individuals are in Asia, not just in the PRC and India but in Indonesia, Viet Nam, and the Philippines. Similarly, a total of 235 million individuals worldwide are unbanked and receiving agricultural payments in cash, and again Asian countries feature prominently in this number. The intersection of these two facts suggests that mobile payments have the potential to revolutionize the way that agricultural transactions take place. Figure 6 shows that even for farmers who have access to financial accounts, 80% of individuals in the PRC, India, and Thailand received at least some of their payments in cash, and in these countries between 5% and 20% of banked farmers received all of their payments in cash. We now move on to a more detailed discussion of the role of FinTech in extending credit and protecting against risk in agriculture.

Figure 6: Payments in Cash for Agricultural Products



Reprinted from World Development Indicators, Global FinDex Database: Gallup World Survey, 2007, Chapter 6, Figure 6.11.

Source: Global FinDex database.

3. CREDIT AND SAVINGS PRODUCTS

Agricultural lending can be seen as a way of understanding the marginal returns to capital in the agriculture sector. In contexts where supply chains are not well developed and poor infrastructure makes input prices high and output prices low, a set of recent experimental studies attempting to extend credit to farmers have typically seen quite weak demand. A microfinance project in a rural area of Morocco facing virtually no competition from other lenders saw takeup of 17% of households (Crepon et al. 2015). Experiences from Sierra Leone and Mali have seen takeup in the range of 21%–25%. The contrast of these experiences from SSA with Asia is quite stark. In Asia, where agriculture is quickly transforming, transportation and processing infrastructure is good, and high-value exports are growing quickly, takeup of agricultural loans has typically been much higher. Asia has a number of pioneering examples of large-scale microfinance institutions that have substantively changed access to credit both within agriculture and more broadly, including Bank Rakyat Indonesia, the Thai Village fund, and the Bank for Agriculture and Agricultural Cooperatives (BAAC) which reports providing access to credit to 95% of farming households in Thailand.

Historically, much of the credit provided to the agriculture sector has either come from state lending institutions or been underwritten by implicit or explicit guarantees from public actors. Given the relatively high probability that such a system will be hit by systematic default driven by weather shocks, public credit institutions have struggled to balance the political pressures to provide a safety net against the financial pressures of long-term solvency. In particular, providing the blend of insurance against unavoidable aggregate shocks while retaining the ability to collect loans under normal circumstances

has proved challenging. For private-sector institutions as well the undiversifiable nature of large-scale agricultural shocks difficult to manage, and is therefore likely to restrict the flow of credit to the sector (Carter, Cheng, and Sarris 2016). Hence farmers in many countries face real barriers to access to credit arising from the intersection of returns and risk. We will argue that state actors have a critical role to play in creating the enabling environment for healthy credit markets, but that ultimately the goal should be to crowd private commercial capital into agricultural investments.

3.1 Microfinance

Ironically, some of the fastest growth in credit to rural areas has come via a modality that was in many ways designed to prevent borrowers from using it for standard agricultural investment. The microfinance revolution, which has brought $102 billion of investment into developing countries and extended credit to 123 million borrowers worldwide (BNP Paribas, 2017), has generally employed a payment model that is explicitly unsuited for agriculture. Borrowers take loans in cycles (most typically four months) with frequent repayment beginning almost immediately after disbursement of the loan. This is an ideal repayment schedule for the cash flow of retail businesses and can with some diversification be made to work for fast turnover agriculture (such as vegetable gardens), but in general cannot be used to finance long-cycle agricultural investment. The picture with regard to microfinance in Asia, however, is quite distinct. Borrowers of the Thailand's Village Fund are not only poor but are disproportionately agricultural (Boonperm, Haughton, and Khandker 2013). Several major Asian microfinance institutions have explicitly created products for agriculture, such as Thailand's BAAC, for which loans to non-agricultural households are capped at 20% (Terada and Vandenberg 2014). In this sense, then, Asia appears to have been uniquely successful at pushing microfinance institutions to serve the agriculture sector.

Several institutional innovations gave rise to the microfinance revolution. First, the concept of joint liability (Besley and Coate 1995; Ghatak and Guinnane 1999) allowed borrowers to be mutually responsible for each other's debts, and consequently to substitute social collateral for physical collateral. This serves to combat both adverse selection (because members will only agree to be jointly liable for those they trust) and moral hazard (because members are incentivized to exert suasion to ensure repayment by their group members), thereby helping to resolve one of the core asymmetric information issues that bedevils credit markets (Stiglitz and Weiss 1981). Second, microfinance lenders typically use high-powered dynamic incentives, whereby borrowers are started with very small loan sizes, and their ability to work their way up to larger loans is predicated on successful repayment of each subsequent loan. Finally, microfinance represents an early form of FinTech in that all MFIs look for ways to decrease costs on the margin by using contracts and technology to be able to offer small loans with minimal fixed costs. Examples include the use of group lending contracts, disbursements and/or payments via mobile money, as well as the use of rapid diagnostics implemented via tablet surveys to target credit toward good or deserving borrowers.

3.2 Credit Reporting

A core linkage between FinTech and microfinance lending is the nature of credit information sharing. Credit bureaus can serve as a critical borrower discipline device (Jappelli and Pagano 1999). Sharing information on total levels of indebtedness may be particularly important in microfinance markets where many borrowers receive loans smaller than their actual demand for credit (due to capped loan sizes necessary to

maintain dynamic incentives), and so may try to borrow from multiple lenders (McIntosh and Wydick 2005). Recent empirical work shows that FinTech innovations can improve targeting of credit even for populations with very little credit history; Bjorkegren and Grissen (2017) illustrate that mobile phone call data records are strongly predictive of default behavior in Rwandan microfinance. Despite the obvious theoretical justification behind the formation of credit bureaus, the actual sharing of credit information presents substantial strategic risks to banks and MFIs (Padilla and Pagano 1997). The institutions that are most important to include are the largest lenders, but these organizations also potentially have the most to lose by sharing (because they reveal more information than they learn), so in practice the path toward the establishment of credit bureau coverage has been a slow and uneven one in the developing world (de Janvry et al. 2010). This combination of potentially large welfare gains with serious incentive problems in the formation of bureaus appears to make this a central area of focus for regulatory policy, since efficient sharing systems may not emerge without governmental requirements.

Institutional details in the design of credit bureaus are critical. Vercammen (1995) presents a theoretical model that shows that while retention of credit information is important, imposing a statute of limitations on the time window of data recorded in the bureau is also important. Without this, individuals may develop reputations that are either so good or so bad that they become relatively immune to recent changes in behavior, thereby dulling incentives for continuous good repayment. Bureaus can also exist at several levels of informational granularity; the most basic of these is a simple list of defaulting individuals; such bureaus are relatively easy to establish and impose some check on asymmetric information problems with respect to default, but do not allow lenders to price risk in any sophisticated way. More complete bureaus contain real-time information on current indebtedness levels of borrowers, meaning that at the time of applying for a loan the new lender can accurately price the risk of default by incorporating the pre-existing debt load. The data and technological requirements for establishing real-time data sharing are formidable for many smaller MFIs who still operate most accounts using spreadsheet programs, but as advanced management information systems and high-speed internet connectivity become more ubiquitous, these obstacles are falling away.

This leaves the regulatory hurdles as a core enabler or obstacle to the formation of information sharing bureaus in microfinance markets. Key regulatory issues in the creation of bureaus include (i) which types of institutions are required to share information, (ii) the exact nature of the information to be shared, (iii) the circumstances under which financial institutions are permitted to query the credit of a potential borrower, (iv) exactly what information financial institutions can observe about queried borrowers, and (v) what the recourse is for borrowers who find that the bureau contains incorrect information on them.

The empirical literature suggests that the introduction of credit bureaus can have a substantial impact on microfinance markets. De Janvry et al. (2010) find that the introduction of a credit bureau into Guatemalan microfinance markets led to a sharp increase in client turnover in the six months after the bureau was introduced. In the month that the bureau was introduced to a branch of the MFI, more than 60% of the pre-existing clients applying for new loans were checked, and 11% of pre-existing borrowers were refused new loans as a result. Those refused were more likely to have defaulted on exterior loans (37% of the refused had defaulted while only 21% of those given loans again had defaulted) and were disproportionately the types of individuals with low repayment (males and more educated clients) and those with more variable repayment

(males). Counterbalancing this exodus of troubled pre-existing borrowers was a huge influx of new individual borrowers who were extended credit; on aggregate, the bureau led to an increase in the number of borrowers of 27% within six months, and generated no deterioration in repayment performance. Despite this strong evidence of enhanced profits for participating microfinance institutions, the Guatemalan credit bureau did not receive strong government backing and has struggled to maintain membership because of the incentive issues described above.

3.3 Asset Registries and Warehouse Receipt Systems

Because much agricultural investment involves purchasing durable equipment (tractors, pumps, tools, combines, water tanks, etc.) it can be self-financing in the form of leasing. For financial institutions, however, leasing presents an identification problem akin to the one addressed by bureaus at the borrower level: when offering a lien on an asset, how can the lender be assured that the same asset has not been promised as security to anyone else? Asset registries may be particularly critical in increasing the flow of credit to smaller producers (De la Campa 2011; Jack et al. 2016). Two policy reforms that have been highlighted as particularly important in the literature are the writing of updated secured transaction laws and the formulation of electronic asset registries that, like sophisticated credit bureaus, allow for the real-time verification of data from the universe of other lending institutions.

A specific form of asset registry that has received a great deal of policy attention is a warehouse receipt (WR) system. This permits farmers to borrow money against grain stored in a warehouse, thereby permitting them to realize cash immediately at harvest time without the grain being sold immediately. Such a system is motivated most strongly in shallow markets with poor producers, where prices tend to be lowest at harvest time but appreciate strongly and predictably in the months thereafter, but where producers lack the capital necessary to delay selling until prices are higher. As long as the rate of price appreciation exceeds the sum of the interest and spoilage rates over the months subsequent to harvest, WR systems should permit a win-win-win, in which farmers achieve better prices on average, financial intermediaries make money on the loans, and consumers benefit via better smoothed agricultural prices (Burke, Bergquist, and Miguel 2018). Unfortunately, WR systems have proven quite complex to build and maintain. They require credible registration of the collateralized grain, as well as deeply liquid warehouse operators who have the ability to extend a large amount of credit. While companies such as Yes Bank in India and Quedancor in the Philippines have worked to establish WR systems (Miller 2008), in general their growth has been limited by issues such as the lack of warehouse capacity, lack of liquidity for warehouse operators, and lack of understanding of the system among smallholder farmers (Shalendra, Haque, and Anu Peter 2016). In addition, WR systems expose intermediaries to substantial commodity price risk (Miranda, Mulangu, and Kemeze 2017). In any case, WR systems can only deal with the limited issue of post-harvest price variation and are not in general a solution to the overarching problem of the lack of financing for long-cycle agricultural investment during planting time.

3.4 Savings Products

Another financial tool to address liquidity and risk constraints is savings, which permits investment as well as enables households to take more risk if consumption can be protected using savings as a buffer. Like credit, enhanced access to formal micro-savings has the potential to improve productivity through both macro-level intermediation effects (Diamond 1984) and micro-level benefits for households

(Rutherford 2000). Recent experimental literature on micro-savings products has found effects ranging from moderate (an increase in formal savings but no overall changes in savings, consumption, or income; see Dupas et al. 2018), all the way up to large and durable impacts of temporary savings products on household expenditures multiple years later (Prina 2015; Schaner 2017). Specific efforts have been made to link micro-savings products to agriculture by aligning them with the input purchase calendar, and "labelling" deposits in accounts as being for the purpose of input use. Brune et al. (2016) use a commitment savings experiment to encourage households to increase investments in agricultural inputs, and find not only savings but investments, agricultural profits, and consumption to be elevated as a result (although they find the increase in investment to be larger than the savings effect, suggesting that the intervention increased the salience of input investment in ways other than the savings account). Carter et al. (2016) find that when households receive subsidies, savings products actually *compete* with agricultural investment, meaning that households with access to savings accounts transfer less of a windfall into future input investment (using it instead to buffer). Hence, access to savings interacts in complex ways with agricultural investment.

FinTech innovations have been used in numerous ways to enable micro-savings. When government transfer programs move from cash payouts to the use of deposits to formal accounts with debit cards, evidence from Mexico suggests that household savings will rise over time as a result (Bachas et al. 2017). No small part of this effect appears to arise from the ability to easily check account balances and verify deposits, thereby raising the credibility of the formal banking system in environments in which trust may be a major obstacle (Callen et al. 2014). Nonetheless, despite the substantial empirical evidence suggesting that micro-savings are beneficial and that FinTech enables these products to scale and to serve clients in new ways, mass-scale micro-savings accounts have been slow to propagate. Interest rates on these accounts is typically zero or very low, regulatory barriers to deposit-taking are substantial, and profits to financial institutions may be limited.

Micro-savings products appear to have strong justification in terms of increased welfare and income among borrowers, as well as in improving overall intermediation and financial depth in the economy. A major obstacle to the scaling of FinTech for savings is that, quite rightly, financial regulators have set strict accounting and liquidity requirements not only for banks but for non-bank financial institutions that wish to begin intermediating savings. This has prevented many smaller, more nimble institutions from being able to capture savings, yet is based on a justified desire to protect citizens from potential loss of savings to careless or unscrupulous deposit-taking institutions. Hence, progress in this area requires careful coordination between policymakers and innovative institutions to allow formal savings to grow in a safe, carefully regulated environment.

4. INSURANCE AND RISK

4.1 Risk in the Agricultural Finance System

Agricultural incomes are subject to substantial covariate shocks, particularly when farming is rain-fed. Recent empirical evidence from Thailand by Samphantharak and Townsend (2018) illustrates that households are more sensitive to correlated (undiversifiable) risks on the margin than they are to idiosyncratic (and hence potentially diversifiable risks). This correlated risk sits at the heart of the agricultural financing system, and the core question is how to structure ownership of this risk in a manner that generates as few distortions to agricultural efficiency as possible. If it remains on the shoulders of farmers, they may rationally underinvest in inputs and thus slow down the Agricultural Transformation. If it moves to the agricultural banking system, it will lead to an under-provision of credit due to the difficulty of hedging this large covariate shock for any but the largest and best diversified banks. Conceptually, we might prefer to shift it to the shoulders of the highly diversified international re-insurers, but this is not always straightforward for reasons we will discuss. Similarly, price risk is an inherent feature of agricultural trade, and smallholder farmers moving into integration with international markets may lose the implicit revenue insurance provided by shallow output markets (when local harvests are poor, local prices in shallow markets are high). In general, the Agricultural Transformation requires farmers to make a set of investments that dramatically increase the financial risks of farming, making issues of risk and insurance paramount.

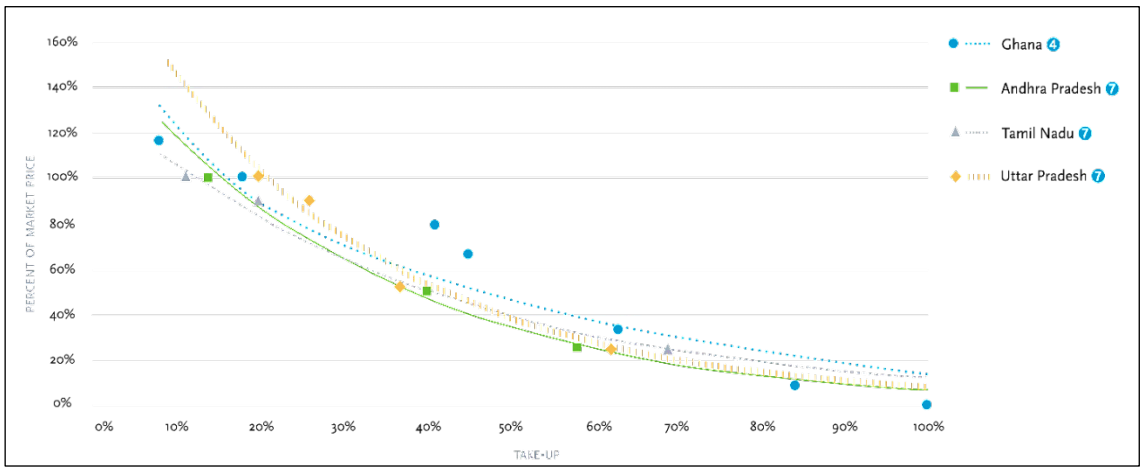
4.2 Micro-insurance

The most important advance in the provision of micro-insurance in recent years has been index insurance. While the insured party typically desires complete insurance as provided by indemnity policies, assessing losses is an expensive process, and indemnity insurance can introduce issues of adverse selection and moral hazard for insurers. Instead, index insurance seeks to find a cheaply collectible proxy for the covariate shock inherent in agriculture and to insure only the component of variation correlated with this index. The most typical examples in practice have been rainfall and Normalized Difference Vegetation Index (NDVI) products, but in monopsony environments where a single buyer has accurate yield information on producers (such as cotton) it has also been possible to build indexes based on area yields or aggregate livestock mortality. The promise of index insurance is that it becomes possible to offer very small insurance contracts profitably because there is no need to loss-adjust each contract separately, and that insurance can be provided with no adverse selection or moral hazard because the object against which insurance is written is beyond the

control of the insured party. Given that much theoretical literature in economics suggests that it is precisely the correlated weather shock that informal risk pooling should be least effective in dealing with (Townsend 1994), there is a strong argument from first principles that index insurance addresses a risk that is not otherwise easy for rural communities to diversify.

Unfortunately, the experience of a large number of index insurance pilots that have attempted to introduce these projects into agricultural markets over recent years has been quite negative (Cole et al. 2013). Not a single study has found robust private demand for index insurance at market prices, and of the many pilots conducted, not a one has moved to scale as a sustainable private market product (Jameel Poverty Action Lab 2016). Several studies have found that interlinking an insurance product with credit, far from untying the Gordian knot at the intersection of credit and risk, actually leads to a *decrease* in the demand for credit (relative to a standalone credit product; Giné and Yang 2009; Banerjee, Duflo, and Hornbeck 2014). A meta-demand curve estimated across multiple randomized controlled trials in South Asia and Africa suggests that at market prices (120% of actuarially fair price), market demand is below 10% of the potential market, and that in order to push demand over 50% of the market, it would be necessary to subsidize index insurance to cost only about 40% of the actuarially fair price (Figure 7). Hence, there seems to be little prospect that micro-insurance will become a large-scale, private-sector means of protecting the agricultural system from weather risk.

Figure 7: Demand Curves for Index Insurance



Reprinted from Jameel Poverty Action Lab, *Make It Rain, 2016*, Policy Bulletin, Massachusetts Institute of Technology.

The core problem is a lack of demand. Why do farmers not want to pay for this product that theory suggests should be so attractive? One obvious reason is that index insurance is only partial insurance; the imperfect correlation between the index and the actual yields experienced on the farm exposes farmers to "basis risk" (Barnett, Barrett, and Skees 2008). In the context of weather index insurance, basis risk is defined as the difference between the variation in actual yields at the farm level (the quantity the farmer wishes to insure) and the variation defined by the index (the quantity actually insured), and may arise either because yields are imperfectly described by the quantity defined by the index (such as rainfall), or because the index measurement is taken in a place other than the farm (hence geographic variation in weather contributes to basis risk). A large stream of literature suggests that the demand response to partial insurance is substantially more complex than perfect insurance (Eekhoudt, Gollier, and Schlesinger 1996), and that the presence of basis risk can introduce non-monotonicity into the way

that insurance demand changes with risk aversion (Clarke 2016). More recent research has focused on behavioral reasons for stagnating demand; the most influential of these has been the idea of "ambiguity aversion," whereby individuals may dislike paying for products when they do not perfectly understand the distribution of shocks and payouts (Gilboa and Schmeidler 1989; Bryan 2010). Additional behavioral explanations are the probabilistic nature of basis risk driving an overweighting of the probability of contract failure (McIntosh, Povell, and Sadoulet, forthcoming) as well as the failure to correctly reduce the compound lotteries inherent in the failure of index insurance products (Elabed and Carter 2015).

In terms of micro-insurance, many of the open avenues for private market product development lie squarely within the FinTech space. First, there is the use of advanced technology to improve the indexes themselves: by pushing down their spatial and temporal level of granularity, it may be possible to squeeze basis risk out of the index. Next, since the credibility and timeliness of the insurance payout seem to be major obstacles, there are opportunities to use scanning technology and the immediacy of mobile money to structure novel insurance products (Prashad et al. 2014). For example, the Kilimo Salama product fielded by the Syngenta Foundation in Kenya links the purchase of a bag of fertilizer to a mobile phone number through a scratch card, and makes an automated payment to the farmer via mobile money if the index pays out, with the cost of the premium embedded in the price of fertilizer.

4.3 FinTech and Risk Sharing in the Agricultural System

Technological innovation is potentially directly conducive to the shifting of risks within the agricultural system simply because it enhances our ability to objectively quantify variation in a fine-grained way. Forward and futures markets play a well-established role in allowing producers and intermediaries to hedge price risk in agriculture. Remotely operated weather monitoring stations, high-resolution satellite-based monitoring of yields, and the use of mobile phones to capture and transmit sentinel agricultural price information all provide novel early-warning systems for weather-driven shocks. Classification of drought events within rich data on weather patterns is the type of problem that big data learning algorithms excel at solving, so there is real reason to think that our ability to build highly predictive indexes is improving rapidly. Unfortunately, in practice, new sources of measurement present the statistical conundrum that to understand their risk properties we need long historical time series, so building a re-insurable index off of a completely novel source of data can prove challenging. Innovation in the financial field, in this sense, is likely to lag innovation in the technical problem of building indexes.

Another conundrum that has been encountered in the development of index insurance products is that, while changing climate only makes the need to insure against correlated shocks more pressing in a welfare sense, it also makes weather risk harder to price. This problem has manifested itself through global re-insurance companies, which understand well that the climate in places like the Horn of Africa and the Pacific coast of South America is changing and are inclined to subject re-insurance in these locations to an additional risk-loading cost. The ability to pass weather risk onto the global re-insurance system is largely one that is priced at private market rates, and such insurance becomes more expensive to acquire as the distribution of global weather risk becomes more unpredictable.

The lack of demand for index insurance may appear less surprising if we examine the way that agricultural risk markets work in developed countries. While future and

forward contracts are commonly used to handle price risk, few completely private agricultural insurance systems exist to serve farmers in OECD countries. Typically, even in countries such as the US that are typically committed to market mechanisms, the government plays a significant role in protecting farmers from weather risk, and these programs are usually heavily subsidized. Other crop insurance systems such as India's National Agricultural Insurance Scheme have reached large scale via a government mandate: in India, any farmer receiving a private-sector agricultural loan is required to insure it through NAIS.

Ultimately, in many contexts it is inevitable that the state will bear many of the costs of agricultural risk protection, whether through the presence of ex-ante commitments (through safety net programs) or through disaster relief. Some evidence suggests that these public safety nets prove an obstacle to the development of private insurance markets (Duru 2016). If this is to be the case, and if demand at the private level is weak anyway, then a natural alternative arrangement would be to use index insurance to protect governments and banks that bear most of the current exposure to this risk. In this sense, given that these entities are likely to be highly liquid, index insurance can be thought of as a loan loss reserve fund (banking) or "rainy day" fund (government) through which budgets can be smoothed and systematic tail risks managed. Examples of this approach include Mexico's CADENA program (de Janvry, Ritchie, and Sadoulet 2016), which uses international re-insurance to underwrite a variety of area-based yield and index insurance programs that state and local governments can decide to purchase for their citizens. In principle, this is an attractive way to handle the systemic risks inherent to agricultural credit systems without the patronage and agency problems that emerge if the government handles tail risks by making budget constraints soft. A closely related development is the issuance of "catastrophe bonds" that make payments in the event a pre-specified disaster occurs. These instruments, widely used in the US, are now being offered in Singapore, and the actively developing market for insurance-linked securities may help to lower the price of transferring risks, as well as developing the bond market in an Asian region that still relies heavily on bank finance (Ralph 2017).

5. COMPLEMENTARY INFRASTRUCTURE AND THE ENABLING ENVIRONMENT

5.1 Mobile Money

Mobile phones and mobile money can provide the infrastructural backbone to provide FinTech services to otherwise marginalized populations. Mobile phones give individuals access to information about prices and business opportunities, thus improving spatial arbitrage (Jensen 2007). Mobile technology also provides a novel impetus to interact with the written word and so can provide a platform to promote literacy (Aker, Ksoll, and Lybbert 2012). The advent of mobile money further extends the possibilities of a mobile phone, providing potential for savings (Mbiti and Weil 2011), and eases the sending of remittances and risk pooling within social networks (Jack and Suri 2014).

The PRC is a standout example of the ways in which mobile payment systems can serve as the backbone for a rapid expansion of a variety of FinTech services. Due to the explosion in e-commerce without a well-developed pre-existing credit card payment infrastructure, the PRC has become the premiere example of how e-commerce and mobile payments systems can reinforce each other. Trading platforms such as Alibaba and Tencent have given rise to a number of different mobile payment systems (Alipay and TenPay together have over 90% of the market share of Chinese mobile payments, although numerous smaller competitors exist). Mobile payments account for almost three-quarters of all online purchases in the country, and are expected to continue to grow by more than 60% in the upcoming year (Chen 2017).

5.2 Financial Literacy and FinTech

FinTech products open up exciting new possibilities, but can also present unfamiliar options to households and require that people be willing to undertake substantial learning costs. Innovations provide households with new ways to organize and discipline their financial lives, but can also open up new danger of over-indebtedness. This tension motivates the importance of financial literacy in the context of FinTech. Over the longer term, financial literacy plays a strong role in allowing households to solve life cycle problems (Lusardi and Mitchell 2014), an issue that will be increasingly important in Asia, a region that combines an aging population with retirees who are being asked to take on a greater responsibility for retirement savings (Yoshino, Morgan, and Wignaraja 2015). Financial literacy has a gender dimension as well, with women having lower levels of financial knowledge in many countries (Xu and Zia 2012). Therefore, financial literacy is a key part of generating true inclusion with FinTech products. The Bayesian justification for FinTech training programs is strong, since a shifting landscape provides individuals with many new choices about which they have not yet had a chance to learn.

While financial literacy is highly correlated with good economic outcomes, there is reason to think that the decision to acquire financial skills is correlated with otherwise positive financial behavior (such as patience; see Meier and Sprenger 2013). Programs attempting to increase financial literacy in an experimental way have generated mixed results, including in some cases substantial improvements in savings and decreases in consumption of temptation goods (Calderone et al. 2018). Simplicity appears to be strongly desirable in training programs tailored to the poorest groups, and “rule of thumb” interventions were been found to be more effective than more complex trainings in the Dominican Republic (Drexler, Fischer, and Schoar 2014). Also, trainings that are tailored by gender can help improve the substantial knowledge gaps that remain. A core point in the welfare analysis of FinTech innovations is that the marginal welfare gain from the use of even relatively primitive communication services may exceed the gain from the more sophisticated services used in more developed countries because they represent such an improvement relative to what was previously available. FinTech investments should be motivated by closing the gaps that prevent marginalized populations from taking full advantage of tools to which they otherwise lack access.

5.3 National and Biometric Identification Systems

Any attempt to build a mass-scale transfer program or credit bureau in a developing country will quickly run up against the problem of how to accurately identify individuals in the population. In countries without robust national identification systems, this turns out to be a challenging task. To move toward full convertibility of mobile money into normal bank savings, countries must satisfy the Know Your Customer (KYC) laws, established by the international system to prevent money laundering. KYC laws place

strict requirements on the types of identification that can be used to create accounts that permit resources to move from mobile wallets into the banking system, and hence identification systems are key to the ability to fully integrate FinTech solutions into the broader economy (ADB 2017).

This issue can also drive substantial leakage from public transfer systems (which may become rife with ghost beneficiaries), and is prohibitive to the construction of robust national credit reporting architecture. This is an area that has seen substantial recent policy work. Countries that lack any clear national ID system have been striving to establish them, and some countries such as Indonesia have been striving to move toward biometric identification (that country's e-KTP identification system covers 86% of the population and is now being used for digital payments in government transfer programs). Countries with paper-based national ID cards may still see substantial improvements in welfare by moving to the use of more sophisticated biometric identification. Muralidharan, Niehaus, and Sukhtankar (2016) analyze the introduction of smartcards into India's massive National Rural Employment Guarantee system (the largest public transfer system in the world), and find that these ID cards substantially improve state capacity, making payments timelier, improving targeting, and combatting corruption in the program. In a subsequent paper, the authors show that the impact of the smartcards on improving the living standards of the poor was so strong as to increase real private sector wages by 6%, driving up consumption in poor households by 13% (Muralidharan, Niehaus, and Sukhtankar 2017).

Even in countries without national ID systems, biometric identification can improve credit market outcomes. Giné, Goldberg, and Yang (2012) implement a fingerprinting system in a single agricultural lending bank in Malawi and find that the use of the technology decreases repayment problems among borrowers who had high ex ante risk of default. This decrease is accompanied by smaller loan sizes and greater concentration of loan resources on business expenditures within this group for the treatment than for the control, consistent with both moral hazard and adverse selection being at play. That biometric technology used by one lender on farmers of a single crop (paprika) can alter credit market outcomes should be cause for optimism; this suggests that it may not be necessary to set up universal, real-time biometric credit bureaus in order to have this technology lead to real improvements in credit market outcomes. Because biometric identification systems can be KYC-compliant even in countries without strong national ID systems, biometrics provide a way to leapfrog legacy paper-based systems and created integrated digital financial services across platforms.

The SIM cards used in mobile phones are becoming the *de facto* form of personal identification in many less developed economies, as mobile money leapfrogs legacy government identification systems. This is a form of identity that bears resemblance to a number of online marketplaces in more developed countries. When reputation hinges on a form of identity that can be shed and restarted (by buying a new phone number, or creating a new login to a trading platform such as eBay or Alibaba), we cannot expect users to ever tolerate a reputation worse than starting over. This has implications for the way that tenure on the system will be scored: when "new" users in a financial platform are in steady state largely made up of past deadbeats re-entering the system, then we expect a long-established reputation (even if checkered) to be strongly preferred over someone with no history. Because of the many services that can be connected to mobile money or other account identifiers, it may be the case that private sector-led modalities for individual identification can function as an effective substitute in states that lack the capacity to identify individuals themselves.

At the other end of the spectrum are efforts to link reputation across many different domains that are currently underway in the PRC. Certainly, applying standard models of

the effects of asymmetric information in credit markets to a more general set of problems (such as crime) indicates that this effort is likely to be effective at controlling specific forms of social misbehavior. However, even setting aside the fundamental civil liberty questions, the linking of reputation across domains has echoes to the long-standing debate in agricultural economics over the role of interlinking in the provision of financial services. In a model in which producers are competitive in all markets but limited in their ability to offer products due to asymmetric information, the interlinking of contracts enhances the ability to offer financial services and will result in an improvement in consumer welfare. If, on the other hand, a single monopolistic provider is able to interlink across multiple markets, that provider can then push the client back to a less advantageous reservation utility and welfare will fall. Given this ambiguity, the improvement of identification systems within one domain (such as credit repayment) has a stronger welfare foundation than the linking of behavior across domains.

5.4 Blockchain Technologies

Blockchain technology has been promoted as the panacea for a wide range of technological problems in recent years. It may be reasonable to approach these proposals with some skepticism in the context of developing-country agriculture, where the use of the blockchain is as yet unproven, and many other institutions may be absent, so the technical dimension of how to build databases is relatively less important. We provide a brief technical background on blockchain technology and then discuss its application to three FinTech problems: blockchain currency as a form of exchange, the use of the ledger in credit bureaus and asset registries, and the uses of blockchain technology in supply chains.

The blockchain is a structured peer-to-peer communication network that uses a specific system of hashes, digital signatures, and timestamp servers to make reliable transactions over a network, eliminating the necessity for an intermediary (Nakamoto 2008). The intuition behind this complex technology of is straightforward: to reduce transactions costs and to allow two unconnected parties to trade in the absence of a trusted intermediary. The blockchain makes use of cryptographic proofs to eliminate this intermediary (typically a bank or other financial institution), allowing two parties to transact directly.

In an example transaction, the receiver of a payment would receive the transfer along with a digital signature that allows the recipient to observe in the hash of the transaction the information of every node that was engaged in the chain. The receiver can verify the signatures of the block to examine the authenticity of the payments, or the chain of ownership of the money in that transaction, and then verify purchase if they are satisfactory. This distributed ledger provides a mechanism that is at once highly secure and easily accessible in a way that many proprietary commercial data networks are not. While much of the emphasis on the blockchain to date has centered on the role of anonymity (as in crypto-currencies such as BitCoin), if the blockchain is to take off in the context of agricultural FinTech, it is likely to be its accessibility that proves its most attractive feature.

Given that digital currency is by far the best established use of the blockchain, it is natural to ask whether this type of currency could serve as a medium of exchange for agricultural trade. Within a country, it would appear that the only justification for using cryptocurrency for exchange would be to evade law enforcement or paying taxes, so is hardly to be recommended as a matter of national policy. For international exchange, it is not hard to imagine digital currency providing an attractive medium in which to conduct business, since with relatively low barriers on both sides of the transaction, it provides a secure way to transact and would be amenable to a variety of "buyer verifies quality" types of contractual arrangements that are important in agricultural trade. In this sense, the marginal value of the blockchain perhaps appears smallest in countries that already have well-functioning legacy systems serving farmers, and the greatest potential gain among those whom current systems do not serve well. However, the enormous gyrations in the value of existing cryptocurrencies such as BitCoin make them an extremely unattractive medium of transaction for intermediaries who already hold substantial price risk in agriculture and will not want to hold this form of currency risk as well. Hence, the maturation and stabilization of cryptocurrency markets may be a precondition for their more widespread use as a standard medium of exchange.

5.3.1 Blockchain Technology in Credit Reporting

The problem of building asset and credit registries, as has been noted by many technical experts, appears to be an ideal application of distributed ledger technology. A blockchain registry network would have the same features as a common distributed ledger network technology, but the blockchain feature could also be used to ensure that the historical record of ownership as well as the transfer of assets, lands, automobiles, homes, and land was current and unambiguous. Although the idea of a transparent registry that records each link in the credit process is promising, several challenges must be taken into consideration, including privacy and the incentives for those institutions that currently possess credit information to share it.

Underlining the challenges to building such a system at scale, the US title insurance industry took in $18 billion in 2006 (Woolley 2006). This provides evidence of the costs imposed by uncertainty over legal title in asset registries, even in a developed country that has a well-functioning integrated reporting system. Most asset registry systems are proprietary and overseen by a single commercial entity, which may well be necessary given the costs of establishing and operating a standard reporting infrastructure. The technological capacity to use a public distributed ledger for asset registries might result in a restructuring of the industrial organization of this sector, and lead to lower costs on the margin. As the barriers to using such a system fall, it is precisely in poorer clients with less valuable assets that we would expect to see dramatic changes in financial access.

5.3.2 Blockchain Ledgers in Agricultural Supply Chains

A key feature of the blockchain—the sequential validity of transactions—is of the highest importance in terms of traceability in agricultural supply chains. Such technology not only can trace back the origin of contaminated food at a much faster pace than conventional methods (del Castillo 2017; Popper and Lohr 2017) but may be the ideal way of structuring the traceability infrastructure that is necessary for the "farm to fork" model of high-value agricultural production (Kim and Laskowski 2018). The blockchain enables transactions in which the buyer places funds for the transaction in a secure escrow, the seller verifies the funds are present and undertakes trade, and then the buyer removes the escrow conditional on being satisfied with the delivery of the contract. So much of agricultural trade involves fast-moving spot

trades on commodities whose quality is difficult to verify and in which trust between buyers and sellers may be low. The attempt to bring greater depth to these markets with ICT-driven trading platforms often runs into trouble over trust and verification when trading changes from being personalized to conducted with strangers. Hence, seen simply as a highly accessible and credible environment in which to conduct exchange with multiple stages of transaction and verification, public distributed ledgers may be useful.

Several large-scale pilots of this idea are underway. IBM and Walmart have created a trial blockchain system for supply chain tracing to allow for better oversight of food safety, and the Chinese giant Alibaba is engaged with PricewaterhouseCoopers in a blockchain trial to monitor food imports from Australia and New Zealand. Indonesian seafood exports are being tracked by Provenance with a blockchain system (Kim and Laskowski 2018). Nonetheless, serious obstacles exist to the full-scale implementation of blockchain traceability: first, these systems require a degree of supply chain sophistication and origin custody tracing that is unusual in developing country agriculture. Proper origin labelling, RFID tags, secure packaging, and integrated intermediary networks may be more important obstacles than the database technology used. Second, profit margins at each stage in the agricultural supply chain may be quite small, diffusing the incentives to invest in systemic solutions even if overall benefits would be large. Finally, blockchain systems are not typically interoperable, meaning that these systems may struggle to achieve in reality the scalability that their technology provides in theory. Nonetheless, this appears to be the most attractive area for the use of the blockchain in agriculture, with a number of advanced pilots already underway in Asia.

6. POLICY RECOMMENDATIONS

Asia is a region with tremendous internal heterogeneity in the macroeconomic importance of agriculture as well as the level of financial development. It is therefore important to tailor policy recommendations in a context-specific manner. To this end, we propose three distinct ways of thinking about the role that FinTech can play in promoting agricultural development in Asia.

6.1 FinTech Policies to Promote High-Value Agriculture

For agriculture to play a constructive role in overall economic growth, the sector must not simply improve overall yields but must achieve the quality control and phytosanitary certifications that will be required to serve demanding urban consumers and to feed into international markets. These are very rarely improvements that can be made at the level of the individual producer, but must instead involve entire value chains that become sufficiently organized to establish “farm to fork” custody certification. In this sense, the key actors may not be farmers but rather processors, intermediaries in the value chain, and certification entities that can allow quality premiums to be captured in final output markets and translated all the way back up the supply chain to the original producers.

Core policy innovations for this objective include:

- Permitting large-scale collateralized credit to agriculture, which will typically require creation of asset registries that permit this lending to take place. Emphasis on financial deepening among input suppliers to permit them to offer capital on lease.
- Well-organized risk markets that can protect the solvency of financial institutions making large-scale investments in agricultural capacity in case of shocks to output. Policies: government and finance institutions use re-insurance markets for tail risks ("risk layering"), catastrophe bonds, explicit underwriting of extreme risk to permit private sector lenders to deepen exposure to agriculture.
- Conceptualizing large-scale financing to agriculture as "value chain financing"; organized, systematic investments across a set of actors to create vertically integrated supply chains feeding high-value urban markets (supermarkets) and export markets.
- Establishing and financing certification entities (phytosanitary, organic, fair trade, etc.) to permit value added in agriculture.
- Contracting innovations to try to push the quality/price gradient that exists in international markets all the way down to original producers; organized intermediaries who can segregate output of different qualities throughout the supply chain.

6.2 Financial Inclusion for the Agriculture Sector

A distinct set of policies is apparent if we think of agriculture as a sector that supports the majority of the world's working poor. Here, financial inclusion is the key concept, in that we must find ways of organizing agricultural production such that they benefit the smallholder farmer as much as possible. In this respect FinTech provides a particularly exciting set of opportunities in that recent advancements in technology may provide enormous benefits to those who have been excluded from legacy systems.

Core policy innovations for this objective include:

- Shifting agricultural payment systems, financial services from banks, G2P payments, and input/output suppliers to function using mobile money infrastructure rather than cash.
- Building credit bureau infrastructure that permits better targeting and performance of uncollateralized credit markets, giving smallholder producers without collateral access to credit.
- A coordinated regulatory push on FIs to require information sharing, particularly on smallholder loans. Emphasis should be on the "ladder of credit," requiring sharing *between* small (microfinance) and large (private commercial) lending institutions so that the entrepreneurial poor can use credit reputation as a tool for economic mobility.
- Financial literacy programs to ensure that individuals are aware of new FinTech options, able to interact with systems and price compare, and using tools to plan for the future. Gender is an important part of financial literacy and programs tailored to specific demographics are more effective.

- ICT-driven agricultural extension services (such as Olam, Precision Agriculture for Development, etc.) that allow smallholder farmers to improve quality, improve profits, and feed output into higher-value supply chains.
- ICT-driven trading platforms to give smallholders access to price information and deeper markets. Shallow markets inhibit smallholders from investing in productivity enhancement because prices fall when output increases.
- Land titling and land registries to permit farmers to collateralize land into credit. Land-collateralized credit may need to be paired with explicit credit insurance to allow borrowers to avoid "risk rationing" on the demand side. Providing agricultural insurance to banks is not sufficient if the banks do not extend this conditionality explicitly in their loans.

6.3 Cross-Cutting FinTech investments

Policymakers at the regional level (such as ADB) can achieve win-wins in the promotion of agriculture by looking for sector investments that enhance both the productivity and inclusivity of the sector. In particular, to the extent that technological innovations can be developed in one context and scaled to others, regional development banks should be looking for "best case" scenarios in which to pilot and develop scalable technologies that can then be reproduced regionally.

Core policy innovations for this objective include:

- Regional regulatory harmonization to permit efficient international trade. Key areas:
    - International harmonization of mobile money and digital payment systems to enhance financial exchange.
    - Harmonization of certification requirements for quality grading, organic designation, food safety, etc.
- Regional approach to risk management so as to allow pooling over as large an area as possible without paying loading costs of international commercial re-insurance. Combine publicly administered risk pools with index-style triggers to avoid political-economy pitfalls over payouts.
- Centralized investments in technology backbone for agriculture:
    - Blockchain-based supply chain architecture. Having been developed in one context this may prove to be highly scalable across countries.
    - Technology to create robust national ID systems and convert them to biometric identification if necessary.

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