Incentives, Institutions and Investment in Private Agricultural Research in Asia

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Abstract

Agricultural Research and Development (R&D) is critical to enhance agricultural productivity and, by extension, feed the world's growing population. Despite the important role that research and innovation plays, the trend of underinvestment in agricultural research is worrisome, especially given the decreasing fiscal ability of many national governments. Increasingly, governments are turning towards the private sector to step up investment.

The research presented in this paper explores the relationship between economic incentives, policies and institutional environment on private investment in agriculture R&D in the Asia-Pacific region. Both a descriptive analysis of key developments in the agricultural industry and the national innovation system, and an empirical study quantifying the effects of the determinants on private investment are conducted. The study uses panel data with information on 7 countries in the Asia-Pacific region from 1995-2003 to test the hypothesis that the expected market sizes for R&D outputs (including both domestic and external markets) and the appropriability of returns from innovation from institutional policies (which includes property rights and institutional environment) can induce greater private expenditure in agriculture R&D. Three linear regression models of private investment in agriculture R&D are built and tested.

Research findings indicate that size of agriculture markets and government effectives have a positive relationship with private investment in agricultural R&D, while economic openness and strength of Intellectual Property Regime (IPR) are found to be negatively correlated to private investment. The results for economic openness and IPR strength reveal that a minimum level of domestic technological capacity is required before developing countries can benefit from increased foreign private investment in R&D efforts.

Agricultural Research and Development (R&D) is critical to enhance productivity and, by extension, to feed the world's growing population. Despite the important role that research and innovation plays, there has been a worrying trend of underinvestment in agricultural research, especially with the decreasing fiscal capacity of many national governments. According to researchers Fan and Saurkar (2008), public expenditure to agriculture as a share of GDP has decreased from over 11% in 1980 to under 7% in 2002. Increasingly, policy-makers and governments are turning towards the private sector to step up investment. In this context, it is crucial for policymakers to understand the determinants influencing private investment in research to implement policies conducive towards incentivizing greater private sector involvement.

The Green Revolution of the 1960s was key in lifting many out of poverty in developing regions of the world. The use of modern technology and crop varieties catalyzed an increase in crop yields and productivity and was instrumental to this success. Thus, even the recent past provides evidence of the profound importance of agricultural R&D in not only enhancing agricultural productivity, but also in addressing pertinent issues of poverty reduction and food security. Further research has also been conducted to highlight the impact that agricultural technology and innovation has on improving livelihood outcomes such as higher income, increased crop yields and better nutrition (Meinzen-Dick, 2004).

However, despite the importance of R&D for agriculture, nations have been consistently underinvesting in agricultural research for decades (Alston *et al.,* 2000). Research compiled by the public sector, typically the sector with the largest stake in R&D in most countries, is receiving stagnant or declining levels of funding, as evident by the global public agricultural research expenditures growth rate of 4.6% in 1976 tapering towards 1.7% in 1996 (Byerlee *et al.,* 2002). Furthermore, public research institutions (especially in developing countries) tend to be run by ineffective bureaucracies and are unable to deliver high quality performance (Rukuni, Blackie, & Eicher, 1998).

Amidst the bleak outlook of declining public levels of investment in agricultural R&D, the private sector has emerged as an increasingly important player in the area of R&D financing. In 2000, the private sector contributed to 40% of total agricultural research expenditure globally (CGIAR, 2005). Furthermore, the growth trend is positive. A study conducted by Pray and Umali-Deininger (1998) of 10 countries spanning both the developed and developing world showed that private R&D expenditure had a compounded at annual growth rate of around 3% from 1986 to 1996. From 1981 to 2000, among the Organization for Economic Cooperation and Development (OECD) countries, spending on private sector research has increased nearly three times as compared to the increase in public sector spending such that the private sector contributed 54% of total agricultural R&D expenditure in OECD countries (Fuglie, 2012). Private expenditure in agriculture research greatly exceeds public expenditure, particularly in the UK, USA, and the Netherlands, in part due to the presence of large pharmaceutical and pesticide industries in these countries (Alston *et al.,* 2000). Private spending on agricultural R&D in developing countries, despite comprising a very modest share of worldwide R&D expenditure, shows a similar upward trajectory of growth (Pardey *et al*., 2006).

There are several recent developments that may be influencing the participation of the private sector in agriculture research. First, there is a greater push for standardization in Intellectual Property Rights (IPR) regimes. The World Trade Organization coordinated the Trade-Related Aspects of Intellectual Property (TRIPs) agreement in 1994, which resulted in stronger international compliance to protect property rights for innovation. Secondly, many developing countries began privatizing their economies in the late 20th century and have adopted free market approaches to growth. The opening of national agricultural markets invited greater participation from the private sector to participate in agriculture research.

Experts assert that greater levels of private spending in agriculture R&D can increase national total expenditure on agriculture research to yield optimal expected returns (Pray,1983). However, challenges and limitations in the market systems of developing countries pose hindrances to galvanizing greater private sector support in financing research. These structural limitations come in the form of weak institutions, instability and high capital risks, smaller and less consolidated markets (Naseem *et al.,* 2010).

Private sector involvement in the Asia-Pacific region is comparatively higher than it is in the rest of the developing world (Beintema, 2008). Concurrently, there exists great heterogeneity among Asian countries with regards to size and growth rates of private expenditure in agricultural research. According to a study by the United States Department of Agriculture (USDA), the country with the largest amount of private research in Asia is India with $55 million annually in the 1990s. In the middle tier level of spending, large to middle income countries such as Thailand, Malaysia and China fell into a similar band of $15 to $20 million per year, and at the bottom tier, mid-size low income countries such as Pakistan see spending of about $6 million (Pray and Fuglie, 2001). Countries such as India and China observed a rapid doubling of private research funding within the last decade of the 20th century, while Philippines and Thailand saw a modest but still impressive growth rate of 60-70%. The dynamic transformation that this region had witnessed in agriculture development makes this region a compelling case for analysis.

The key research goal of this study is to investigate factors and conditions that influenced greater private sector investment among countries in the Asia-Pacific region. In particular, this study seeks to establish the conceptual framework around the determinants of private investment in agricultural R&D, to examine the key trends and developments in the Asia-Pacific Region, to empirically quantify the impact of selected determinants on private agricultural R&D investment and finally to Explore implications on policy,

The findings of this paper will be useful in guiding policymakers' decisions in identifying the range of policy options that can better incentivize private sector investment in agriculture R&D in developing countries.

Literature Review

The factors influencing the level of private investment in agriculture R&D within Asian countries are multifaceted and diverse. Drawing from a multitude of disciplines ranging from economics, political science, and organizational behavior, the literature elucidates from both micro and macro perspectives on the key determinants of private agriculture R&D. Some scholars have examined the economics behind investment decisions of for-profit private firms. Conversely, others are concerned with the enabling environment of states and the interactions among multiple stakeholders that facilitate private sector development. These complementary perspectives enhance the collective understanding on the role the private sector plays in agricultural research among developing Asian countries.

From a neoclassical economics perspective, the analysis focuses on the individual private firm as a rational unitary actor. In this light, the profit-maximizing objective is a key determinant of private firms' R&D investment decisions. Economists like Pray and Echeverria (1999) and Narrod and Fuglie (2000) have reframed the profit-maximizing objective of firms into three main determinants of private R&D investment: a) size of market, b) appropriability of economic returns from R&D, and c) cost factors.

The larger agriculture sector, the more attractive the sector becomes to investment, thereby leading to higher the levels of private agriculture research investment. Pray and Fuglie (2001) found a weak positive relationship between private research expenditures and agriculture gross domestic product (GDP); countries with relatively higher incomes like Malaysia and Thailand have higher private research intensity than do countries with lower incomes like Indonesia and Philippines.

The size of the agriculture market is in turn influenced by the expected domestic consumer demand, the openness of the market to the global economy, and purchasing power of buyers of R&D outputs. Expected demand for agriculture inputs and consumer products allows firms to predict market size of their research output. The demand is contingent on population size, income levels, and consumer dietary preferences. Empirical research in India has shown that higher incomes and urbanization increased the demand for high-quality food and processed food in the last two decades (Pray and Latha, 2012). As Indian farmers responded by increasing agriculture production outputs from 223 metric Ton (MT) in 1990s to 336 MT in 2008 through the use of modern inputs, the demand for agriculture R&D output increased such that investment in research became more attractive. A corresponding increase followed in private R&D investment, rising from USD 272m to USD 563m in India.

Demand exists when consumers are willing and able to purchase goods; hence, the purchasing power of farmers to access R&D outputs is another way in which firms assess market size. In developed countries such as the US, farmers with access to large-scale, capital intensive farm operations utilize high levels of technology and innovation. However, in developing countries, smallholder farmers lack the purchasing power for R&D outputs (Naseem *et al,* 2006). This explains the disparity in levels of private R&D investment between the developed and developing world. The divide is projected to decrease as the commercialization and consolidation of smallholder agriculture in developing countries opens up new market opportunities for private-sector agriculture R&D firms (Pray and Umali-Deininger, 1998).

The size of the market can increase when a country is open, well integrated into the global economy, and can respond to changes in the international demand of agricultural products through their export industries. Openness to trade allows the extension of the domestic market into the international arena. In the Philippines, the growth in export markets stimulated private R&D investment (Pray and Fuglie, 2001). This relationship is observed also in Colombia and Kenya, where private agricultural research is growing particularly among export crops (Estrada *et al,* 2002). Economic openness also enable private firms to access capital, technology, information across borders, and facilitate greater foreign direct investment that can strengthen the agriculture industry (Gisselquist and van der Meer 2001).

Appropriability refers to the ability of the firm to capture the economic benefits of an invention. The stronger the appropriability, the higher the levels of private R&D investment as the returns on investment become more rewarding. The ability to capture returns is dependent on the structure of the industry, the characteristics of the technology and intellectual property regimes (Pray and Fuglie, 2001).

Market structures determine the amount of rent a firm can appropriate from research. Schumpeter (1950) hypothesized that monopolistic or oligopolistic industries have higher rates of innovation. According to their findings, it is easier for firms to appropriate the gains from research when it has strong market power to set prices. There is empirical evidence for this: Brennan et al (2001) show that market concentration in the US biotechnology industry increased appropriability of research, and increased R&D intensity.

Furthermore, certain types of technology have characteristics that make appropriating the benefits of research easier for private firms. Hybrid seeds are example of these technologies, as they have inherent genetic biological properties that makes it hard for farmers to reproduce seeds on their own, and thus farmers have to depend on the innovating firm to obtain seeds for each planting. Therefore, private sector firms are more likely to concentrate their research in these crops (Spielman *et al*, 2012). A study in 2003 showed that an estimated 70% of hybrid maize seed was supplied by the private sector (Nikhade, 2003).

Finally, legal mechanisms such as Intellectual Property Rights (IPR) create an exclusion mechanism that protects the innovating firms and allow firms to reap the returns on their investment. With regards to agriculture, there are different forms of IPR: patents, trade secrets, copyrights, Plant Variety Rights (PVRs) and Plant Breeders' Rights (PBRs) (Rafiquzzaman and Ghosh, 2001). PVP protects the genetic makeup of a specific plant variety, and allows exemption for breeders and farmers that enables farmers to use protected varieties for future breeding (Koyek, 2001). These IPR laws come into effect through the propagation of multilateral treaties and bilateral agreements. With the inclusion of Trade-Related Intellectual Property Rights (TRIPS) among the World Trade Organization members, many developing countries have adopted some basic intellectual property rights, including those for biotechnology and agriculture (Perrin, Hunnings, Ihnen, 1983). The International Convention for the Protection of Plant Varieties (UPOV) is another global standard that advances the rights of plant breeders which many countries are conforming to, especially when bilateral trade agreements with the US are negotiated on the basis protection of plant variety (World Bank, 2006).

The literature has been divided on the empirical impacts of IPR on innovation. Studies by Alfranca and Huffman (2003), and Kanwar (2006) have shown that stronger IPR protection is significantly positively correlated to amount of R&D investment. They posited that there is less uncertainty among private firms that rival competitors will appropriate their innovation in the presence of strong legal IPR framework, leading firms to be more incentivized to conduct research. However, among developing countries, the impact of IPR especially is inconclusive. There are scholars who cautioned that strengthening IPR standards may disproportionately harm developing countries and stunt their progress at domestic innovation. Thompson and Rushing (1996) and Leger (2006) found differential effects of IPR between developed and developing countries. Their studies indicate that while IPRs had a significantly positive effect on economic development for advanced industrialized countries, it had an insignificant effect on developing countries. Lall (2003) argue that for developing countries with lower levels of technological capacities and are dependent on adapting and learning from foreign technologies, stronger IPR will not have a stimulating effect on local innovation. Additionally, Chen and Thitima (2004) found an empirical U-shaped relationship between levels of IPR and level of economic development of countries. Their paper established that at low level of developments, there is a trade-off between stronger IPR and learnings from imitation, but as countries develop, promoting IPR helps to incentivize domestic innovation.

The intricacies surrounding the implementation of IPR legislation require in-depth analysis on effective institutions and enabling political environment, and this will be discussed in later sections.

The cost of innovation is a function of technological capability and price of scientific inputs. When costs are low, firms are better incentivized to invest more in R&D.

Advancement in technology drives the cost of research down by increasing productivity and efficiency of research. In the case of research among livestock, developments in reproductive technology such as artificial insemination led to faster genetic improvements, a greater number of offspring bred, and shorter gestation periods. Concerning livestock production, broiler poultry has the shortest gestation period as a result of technological advancements while beef and dairy have the longest. Private investment is consequently greater in the former than in the latter two (Narrod and Fuglie, 2000).

With regards to scientific inputs, a key location-specific consideration for private firms is the domestic supply of skilled human capital. In the Philippines, the supply and low cost of hiring local research staff encouraged certain multinational firms to move their research programs to the region (Pray, 1987). It is important to note that the domestic supply of skilled human capital is greatly reliant on domestic investments in education (Pray and Naseem, 2003).

While economics offers a conceptual understanding of the incentives that influence a private firm's decision to invest in agriculture R&D, the literature also highlights the need to consider the macro-context in which these firms are situated. The political economy and policy regime of a country create enabling environment for the development of private actors and strengthen their involvement in agriculture R&D efforts.

The shift towards greater market liberalization among Asian developing countries is responsible for the growth in private R&D levels within agriculture. As states loosen their monopolistic grip in the market while liberalizing their state-owned monopolies. Pivate actors, both foreign and domestic, have been shown to step into the marketplace (Chadha *et al,* 2013). Research conducted by Pray and Fuglie (2001) reflects this trend. The most liberal market economies in the mid-1980s—Thailand, Malaysia, and the Philippines— had the highest private research intensities, while the countries with the most controlled economies—China, Indonesia, Pakistan, and India—had the lowest private research intensities. The latter group, which experienced rapid liberalization program in latter decades, also saw a corresponding increase in their private research intensity.

As markets liberalize, regulatory reforms and policy changes affecting agriculture input industries influenced the way private actors perceive incentives. Previous studies of private R&D within India's the seed industry (Ramaswami and Pray 2001) and private agribusiness R&D in Asia (Pray and Fuglie 2001) recognized the role market liberalization played in facilitating conducive trade policies that attracted large companies and foreign firms into domestic food and agriculture industries of various countries. In India, policy reforms such as the New Policy on Seed Development (1988) and the New Industrial Policy (1991) removed import bans and quotas and institutionalized Intellectual Property Rights in compliance with the WTO agreement. This led to significant investments in agricultural input industries by almost all large Indian business groups, and also by multinational corporations (MNCs), which brought their technical expertise into the domestic market (Pray and Nagarajan, 2012).

Market reforms also lead to conducive policy regimes and institutions with effective regulatory regimes and enforcement procedures that can incentivize private investment. The role of intellectual property rights comes to the fore yet again. IPR requires the presence of effective regulatory and judicial system to enforce these IPR. Naseem et al. (2010) argue that the weak institutions in most developing countries complicate effective implementation and enforcement of IPR. Empirical studies by Ginarte and Park (1998) found that the institutional climate of a country, such as political and market freedom, plays a more instrumental role in influencing strength of IPR regimes than the country's level of income per se.

While the last few decades have witnessed a worldwide trend of market integration and increased privatization, socialist economies in transition with a legacy of planned economies face a unique set of challenges that have implications for the role of private sector involvement especially in agriculture. Using Soviet countries as examples, Clayton (1992) argues that socialist economies in transition faced challenges such as distortion of price signal through government intervention, bureaucratic barriers of inefficiency, restriction on property rights; these challenges dampen incentives for the private sector. Beintema and Stads (2008) attributed the underdeveloped private sector in Laos to the country's socialist past in this regard.

Researchers have also advocated taking into consideration the complex relationships between the private sector and multiple stakeholders to understand the factors influencing the levels of private R&D investment. The major actors include multinational corporations and foreign firms, as well as national and international research institutions from public sector.

The growth of large multinational corporations as a result of industry consolidation has implications for institutional capacity in developing countries to facilitate investment in private agriculture research. In developed countries where these MNCs are based, there is an increased concentration of firms controlling key platform technologies that are necessary for downstream and applied research (Naseem, Omamo and Spielman, 2006). In the United States, the four-firm concentration ratio, an indicator used by economists to measure the level of monopoly in an industry, in the cotton seed market reached 87 percent by 1998, while the ratio reached 67 percent in the corn market and 49 percent in the soybean market (Hayenga and Kalaitzandonakes. 1999). Given that these large multi-national firms use trademarked technology in their research, facilitating their participation in developing countries necessitates that developing countries institute mechanisms for technology transfer into the local context. Creating the bonds that lead to participation can be done either directly through foreign direct investment or indirectly through partnerships. The establishment of mutually beneficial institutional arrangements is important in facilitating knowledge transfer and increasing the level private investment in R&D (Naseem, Omamo and Spielman, 2006).

The role played by the public sector is also important in determining the level of private investment in agricultural R&D. Public-sector efforts in basic research complement the work that the private sector does in applied research through coordinating institutions that integrate private research centers into the national research framework (Hall et al. 2001). Public research, such as basic research in concepts and methods, or by the provision of improved germ plasm, inbred breeding lines, and foundation seed at nominal costs, generate positive spillovers that reduce the cost of private R&D (Pray and Fuglie, 2001). Evidence suggests that the private sector complements public-sector agricultural research in Asia. A study in India found that the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) serves as a major source of germplasm for sorghum and millet breeding firms, supplying nearly 65% and

80%, respectively, of private firms covered in the study's survey (Pray *et al,* 1998). In addition, research in seven Asian countries has found that public and private research expenditures and research intensities have been positively correlated for the last two decades (Pray and Fuglie, 2001).

Functional markets, conducive political enabling environment, and systemic institutional interactions with stakeholders all work in tandem to facilitate the entry of private sector actors in agriculture. While private actors respond to incentives in a rational manner, the attractiveness of these economic incentives is strengthened by the presence of effective policies and a cohesive research eco-system. When actors along the agriculture value chain are able to respond to increasing market demands, and when the necessary enabling environment and facilitating institutions are established, the system increases its capacity for innovation (Anandajayasekeram, 2011).

However, the literature contains a significant gap in understanding the relative importance of individual factors – specifically, economic incentives and the institutional environment – in developing countries. There is also a lack of sensitivity to the question of primacy among these factors in influencing private sector involvement. This overall lack of specificity is a deterrent to effective decision-making in public-sector resource allocation. Consequently, this study aims to provide clarity by leveraging the variance in the macro-level political economy that exists among Asian nations to analyze the relative influence that economic and institutional factors of profitability and appropriability have on private expenditure in agriculture R&D.

Agricultural Development in Asia

Over the past couple of decades, the transformation that Asia has witnessed in agricultural development has been instrumental in improving living standards in this region, where agriculture is still the foundation of many national economies. The following section will seek to analyze the key trends over the last three decades in agriculture industrial policy, innovation policy and to contextualize their impact on private research.

The countries selected for this study include all seven countries in the Asia-Pacific region for which the dataset of Agricultural Science and Technology Indicators (ASTI) have information regarding private investment in agriculture R&D: Malaysia, Indonesia, Philippines, Papua New Guinea, Vietnam, Lao, Sri Lanka. This selection provides an interesting spread of countries across different income groups, political economy and market systems. According to categorization by OECD (2014), Indonesia, Malaysia and Philippines are considered upper-middle income countries, while Laos, Vietnam, Sri Lanka and Papua New Guinea are considered to be low-middle income countries. Vietnam and Laos also have a history of operating under a planned economy and are currently in transition towards a market economy. Information about the countries' GDP/ Capita can be found in Table 1, which depicts the range of early-stage countries such as Papua New Guinea, Vietnam and Laos with GDP/Capita of less than $2000 to advanced countries like Malaysia with GDP/Capita above $10,000. Countries in the earlier stages of economic development typically have economies based in primary industries like agriculture, while countries at a higher stage of growth transition away from the primary industries to support secondary and tertiary industries. Table 1 also reflects this inverse relationship between dependency on agriculture and the level of economic development across the 7 countries.

Table 1 GDP/Capita of 7 Asia-Pacific Countries

Countries	GDP/Capita (PPP$)		Agriculture (% of GDP)	
	1990	2005	1990	2005
Malaysia	10,155	17,921	15.2	8.3
Indonesia	4,295	6,510	19.4	13.1
Philippines	4,010	4,804	21.9	12.7
Sri Lanka	3,340	5,843	26.3	11.8
Lao PDR	1,622	2,930	61.2	36.2
Papua New Guinea	1,610	1,779	30.9	37.7
Vietnam	1,501	3,485	38.7	19.3

Source: World Bank

In the 1970s, most countries in the study were in the early-intermediate stage of economic development with predominantly rural economies, some of which are heavily dependent on primary agricultural exports (Van *et al*, 2012). In the early stages of development, the emphasis is on achieving self-sufficiency in food and reducing poverty (Diao, 2007). National governments respectively played an active role in agricultural and rural development to achieve those welfare objectives. In the early 1970s, the Indonesian government focused on assisting small-holder farmers and producers with the introduction of the Mass Guidance Program (BIMAS) for rice production. The government subsidized the input market for rice farmers under this policy and determined guaranteed prices for crops. (Fuglie, 2001) Similarly, in the 1990s, the government in Philippines chose to enact protectionist agriculture policies to protect local farmers by placing quota restrictions on agricultural produce and regulation over seed inputs. (Pray, 2001) The role of the central government was also especially strong in planned-economies like Vietnam and Laos until the late-1980s.

Widespread economic liberalization across Asia took place in the 1980s (Haggblade *et al*, 2002). In Indonesia, as a response to increasing pressure from international organizations like the International Monetary Fund (IMF), trade tariffs on several agricultural commodities were reduced and state trading monopolies on rice, wheat, and soybean trade were eliminated. The Indonesian government also lessened the degree of market intervention by eliminating the subsidies on pesticides and fertilizers, thereby reducing their role in agricultural input procurement and distribution and lifting restrictions on size of livestock and poultry operations (Fuglie, 2001). Export taxes on copra were eliminated in the Philippines, while quotas and tariffs on agricultural inputs were lowered considerably (David, 1996). As a whole, the region also embraced regional integration, as evidenced by the multilateral free trade agreements (FTA) by Association of South-East Asian Nations (ASEAN) and South Asian Preferential Free Trade Agreement.

The shift is also evident in socialist countries like Laos and Vietnam, which adopted a series of economic and political reforms to transform their centralized planned economy into a market-based economy during that time. This led to decentralization of state power, privatization of State-Owned Enterprises (SOEs) in agriculture and trade liberalization (Than, 1996). In Laos, the Agriculture Investment Promotion Policy allowed investors in the agriculture sector to enjoy tax incentives. The reform process is slow, however, and Vietnam and Laos still lag behind their neighbors in terms of economic openness. In Laos, permits are still difficult to obtain for private-sector start-up companies in agriculture and standardized tax laws are largely absent. Similarly, the Vietnamese government continues to maintain a highly interventionist stance. Only 10 percent of rice exports there are from the private sector; the remaining 90 percent is contributed by public sector companies, most prominent being VINAFOOD1 (exports from northern Vietnam) and VINAFOOD2 (exports from southern Vietnam) (Briones, 2013).

These reforms had implications across the agriculture value chain that impacted both the agricultural production industry and the agricultural input industry downstream (which includes the seed, fertilizer and chemical markets). First, with economic and trade liberalization, farmers and producers were better able to react in a more flexible manner to growing demands of the food market, resulting in growth of agricultural production. As countries progressed in their economic development, and real GDP per capita grew for many countries in the region during the 1990s, there was an accompanying change in diets. Demand for processed food increased following urbanization, leading to rapid spread of supermarkets across Asia (Reardon *et al,* 2012). Expanding export demand especially from small, resource-poor countries such as Singapore and growing domestic demand were major growth impetus for commercial swine production in Indonesia and poultry production in Malaysia (Fuglie, 2001). Foreign demand for exports of commodities such as rubber, palm oil, and fruits contributed to farmers and plantation owners investing in their production efforts. In 2007, amongst the 20 top companies with agricultural production as core business, close to 50% were based in Asia (UNCTAD, 2009). In addition, within Asia, Malaysia and Indonesia are the world's two largest exporter of rubber and oil palm. As a result, private R&D tend to be concentrated in cash crops such as such as oil palm, rubber, tea, vegetables, and horticulture; hybrids of rice, sorghum, millet, and maize; and livestock hybrids, such as poultry (Pray and Fuglie 2001; Gerpacio 2003; Tripp and Pal 2001; Morris 1998).

Second, as a result of increased agriculture production in key commodity chains, farmers were motivated to improve their productivity through use of better inputs, leading to development of the agriculture input industry. In response to demand for high-yielding crop varieties, private companies invested in breeding programs for better seed varieties, while placing great emphasis on hybrid seeds. Key players include a mixture of joint ventures with foreign multinationals and domestic corporations such as the East-West Seed Company (Dutch), Cargill (US), Golden Hope (Malaysia), Charoen Pokphand (Thailand), and PT Londsum (Indonesia). In addition, use of agricultural chemicals also increased, as farmers sought greater levels of crop protection and soil fertility. Research was conducted to adapt modern technology for tropical climate in Asia. Major multinational companies such as Monsanto, Dupont Pioneer, Zeneca and Novartis were pivotal in establishing technology development and transfer in the region. For example, Zeneca maintained four field research stations in the Asia- Pacific region (Malaysia, Philippines, Thailand and Japan) to adapt new chemical compounds for weed and rodent control under tropical conditions (Fuglie, 2001). Research by Dole and Del Monte in Banana Plantations in the Philippines helped to reduce the cost of production by tailoring the use of nutrients to local soil and climatic conditions (Pray, 2001)

These trends in agricultural development impact different countries to different extents. As reflected in Table 2, the relatively more developed countries with larger domestic markets like Indonesia, Malaysia and Philippines have higher numbers of private research units compared to the other less developed countries like Laos, Vietnam, Sri Lanka and Papua New Guinea.

Table 2 Private Research Units by Country

Research Focus	**Number of Private Research Units in 2005/6**						
	Indonesia	Malaysia	Philippines	Sri Lanka	Vietnam	Papua New Guinea	Laos
Coconut palm		1					
Coffee		1					
Crops	2	5	7	2			
Forestry	5		1				1
Fruit			7				
Livestock			1				
Livestock, fisheries			1				
Oil palm	3						
Oil palm, cocoa, Rubber	1						
Ornamentals			1				
Palm oil		5					
Pesticides, herbicides		1					
Sugar cane	1	2				1	
Sugar cane, Palm Oil	1						
Vegetables	1	1	1		1		
Crops, Livestock						1	
Grand Total	**14**	**16**	**19**	**2**	**1**	**2**	**1**

Source: ASTI

National governments of many countries in the region have expended considerable effort to develop national research systems and implement Science and Technology (S&T) policies over the past few decades.

In the post-Green Revolution era, there begun a growing recognition of intellectual property rights internationally, especially for living organisms. In 1995, the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) came into effect for member countries of the World Trade Organization, which stipulated the provision for IPR protection for all invention, including genetic resources, by 2000 for developing countries and 2006 for least-developed countries. Exemption for "plants and animals other than micro-organisms and essentially biological processes for the production of plants and animals other than biological and microbiological processes" is allowed under TRIPS, provided that member countries establish "an effective sui generis system", or independent system, particularly with regards to Plant Variety Protection (PVP) (Blakeney, 1996). Although there has not been widespread adoption of the UPOV standards in Asia, there has been a trend towards harmonization of international standards. External pressure exerted by developed countries in bilateral trade negotiations is a factor that influenced local governments to comply with international standards. For instance, the US-Vietnam bilateral trade agreement in 2000 is agreed upon Hanoi's enactment of UPOV standards (Boyle, 2001). As a result, countries have increasingly adopted national standards of protection that conform with the principles of UPOV as seen in Table 3.

Table 3 IPR Status by Country

Countries	WTO Membership	Participation in UPOV	Membership in ITPGRFA	PVP Law
Indonesia	1995	-	2006	Acts No.29 the Year 2000 on Plant Variety Protection
Malaysia	1995	-	2003	Protection of New Plant Varieties Act 2004 (Enforcement in 2007)
Philippines	1995	-	2006	Republic Act No.9168 : An Act to Provide Protection to New Varieties, Establishing a National Plant Variety Protection Board and for Other Purposes (Enforcement in 2002)
Sri Lanka	1995	-	2013	Protection of New Plant Varieties Act (draft)
Lao	2013	-	2006	Intellectual Property Law 2007 (Enforcement in 2008 /Amended in 2011)
Papua New Guinea	1996	-	-	-
Vietnam	2007	Act of 1991	-	Law On Intellectual Property(No. 50/2005/Qh11)

Source: WTO, ITPGRFA (International Treaty on Plant Genetic Resources for Food and Agriculture), UPOV, EAPVPF (East Asia Plant Variety Protection Forum)

Many countries in Asia have also witnessed the creation of national research agencies which fall mainly under the purview of the Ministry of Agriculture to promote the development of agricultural R&D. These include organizations like the Malaysia Technology Development Corporation (MTDC), Indonesian Agency for Agricultural Research and Development (IAARD), Philippine's Department of Science and Technology (DOST), Laos National Agriculture and Forestry Research Institute (NAFRI) and Sri Lanka Council for Agricultural Research Policy (CARP). These agencies encourage cross-sector collaboration, establish linkages between public and private research agencies, and promote technology transfer. In Malaysia, public research organizations are structured along commodity lines: Malaysian Palm Oil Board (MPOB), the Malaysian Rubber Board (MRB), and the Malaysian Cocoa Board (MCB), work closely with private agribusinesses. In 1992, the Malaysian government also supported the establishment of a separate corporation (MARDITECH) that offers joint equity partnership with private companies to commercialize new technology, and offered tax incentives for private research where companies can write off 200% of the research investment (Fuglie, 2001). An example of a cross-sector partnership is the joint venture between Sime Darby, a large Malaysian palm oil, rubber and cocoa producer, and the International Plant Research Institute, to establish an ASEAN Biotechnology Corporation. (Pray, 1983) In Indonesia, the government collaborated with external donors like the World Bank and Asian Development Bank (ADB) to develop the Agricultural Research Management Project (ARMP) and the Participatory Development of Agricultural Technology Project (PAATP). These projects set aside special funds for collaboration between IAARD scientists and universities, international research centers, and private-sector companies (Fuglie and Piggott 2006).

Empirical Study

The following section seeks to investigate the quantitative impact that economic incentives and institutional factors have on influencing levels of national aggregate private expenditure for agriculture Research and Development (R&D). The hypothesis is that the expected market sizes for R&D outputs (which includes both domestic and external markets) and the appropriability of returns from innovation from institutional policies (which includes property rights and institutional environment) can induce greater private expenditure in agriculture R&D.
Population Selection

The dataset consists of a time panel with 47 data points covers the time period 1995 to 2003 (albeit with some gaps in data) from 7 Asia-Pacific countries: Indonesia, Malaysia, Philippines, Laos, Vietnam, Sri Lanka, Papua New Guinea.

The time period selected for analysis was primarily driven by the availability of data, and it is important to acknowledge two significant events that took place within this time period that would impact the variables under consideration. First, the universal enforcement of the World Trade Organization (WTO)'s Trade-Related Aspects of Intellectual Property Rights (TRIPS) occurred in 1995, and this influenced the appropriability of the returns from innovation by strengthening intellectual property rights (Blakeney, 1996). Additionally, the Asian Financial Crisis, which took place in 1997- 1998 served as an exogenous shock to the economic system of many countries and dampened private expenditures across the board.

The dependent variable is the national aggregate annual real private expenditure on agriculture R&D. The source of the data will be based on secondary information published by the Agricultural Science and Technology Indicators (ASTI) initiative led by the International Food Policy Research Institute (IFPRI). For a graphical representation of how levels of private expenditure vary across time and by country, refer to Figure 2.

Researchers at ASTI collected information through surveys and in-depth interviews of agribusiness firms in these countries. The researchers were cognizant of the difficulties surrounding collecting complete and accurate private data in developing countries, where private research activities tend to be small and ad-hoc in nature, due to confidentiality concerns and limited accessibility of information. The focus is restricted only to national agricultural research systems, which include domestically targeted research activities that are executed by the public or private sector within a particular country and excludes research by international research agencies. The private sector is comprised of both business and public enterprises owned by government with the aim of producing profits.

To ensure that cross country and cross time comparison of agriculture expenditure is possible, private expenditure will be converted via the Purchasing Power Parity (PPP) index and compared to a standard base year. This eliminates deviation arising from different exchange rates, and inflation rates across countries. A logarithmic transformation is applied to amount of private expenditure to ensure a linear fit with the model.

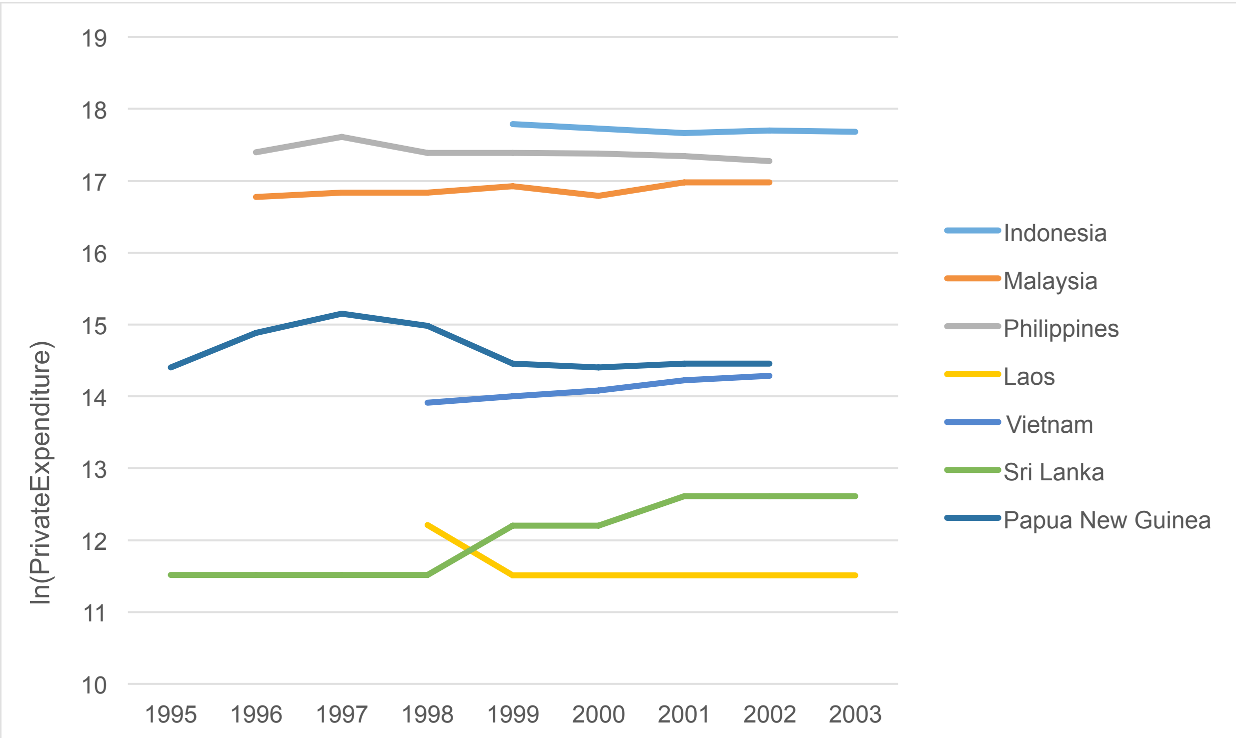

Figure 1Private Expenditure in Agriculture R&D in select Asian countries

Multiple independent variables are selected to account for both expected profitability and appropriability of research returns. These four independent variables have been carefully selected and defined in a manner to ensure there is no co-linearity among them.

Both the size of markets and their economic openness are factors that influence expected profitability. The size of national agricultural market for research is measured by the value of agricultural Gross Domestic Product (GDP) output at PPP index. This variable is the primary independent variable under consideration. Following the methodology of previous scholars (Payumo, 2011), this value will be derived by multiplying the value-added agricultural component as percentage of GDP with the respective GDP of the country in PPP($). Both of these indicators can be found in the World Development Indictors (WDI) by the World Bank. A scatter plot visualizing the relationship between the natural log of Agriculture GDP and level of private expenditure is shown in Figure 2.

Economic openness is proxied by the component 'open market freedom,' which is one out of the four pillars of economic freedom found in the Index of Economic Freedom compiled by the Heritage Foundation and Wall Street Journal. Open Market Freedom is a composite measure of Trade Freedom, Investment Freedom and Financial Freedom. Among the multiple types of measures to represent trade openness, a composite index was selected because scholars recognize the ability of a composite index to take into account multiple aspects of trade policy into a single measure (Lane, 2013). The Index of Economic Freedom is a composite index superior to other composite indexes such as the index created by Sachs and Warner (1995). Although the Sachs-Warner index was used in Huffman and Alfranca's 2003 study that investigated determinants to private agriculture R&D expenditure among European countries, it is currently outdated and other scholars perceive that the binary nature of the measure (either 0 or 1 scoring) contributed to its inability to capture the multi-faced nuances of the trade liberalization process (Lane, 2013). Trade openness could also be proxied by the volume of international trade as a percentage of GDP, an indicator used by Chen and Thitima (2004). However, this cannot be considered in the model for this current study as there will be a close relationship between trade as a percentage of GDP, and the prior indictor of agriculture industry as a percentage of GDP.

With regards to appropriability of returns, both the comprehensiveness of the Intellectual Property Right (IPR) regime and the institutional environment concerning the effectiveness of governance are independent variables under consideration. These two variables are independent of each other conceptually because the strength of patent protection is not conditioned on the effectiveness of the state and the credibility of the government's commitment to their policies. .

The Index of Patent Rights developed by Ginarte and Park (2008) for 122 countries from 1960 to 2005, reported in 5 years interval, will serve as a proxy to measure strength of national IPR regimes. This authoritative index is not only comprehensive in its scope of coverage of countries, time period, and aspects of IPR laws, but has also been extensively cited by 1080 scholarly articles. The index is the unweighted sum of five separate scores for: coverage (inventions that are patentable); membership in international treaties; duration of protection; enforcement mechanisms; and restrictions (for example, compulsory licensing in the event that a patented invention is not sufficiently exploited). These 5 separate scores contains 18 measures of regime strength, 11 of which are related to coverage of agricultural technology: coverage for plant and animal varieties, and also for microorganisms; membership in International Union for the Protection of New Varieties of Plants (UPOV). Research built on this index found that industrialized countries have higher level of protection while countries in Asia, Latin America and African have lower level of protection (Nunnenkamp and Spatz, 2003). While limitations exist in referencing an index that was only updated every 5 years to this research dataset that covers a span of 2 decades, scholars have found ways to approximate scores to a continuous series by extrapolating recorded scores two years forward and two years back (Spielman, 2003).

Government effectiveness will be based on the Worldwide Governance Indictor (WGI) project conducted by the World Bank. This captures perceptions of the quality and efficiency of civil service and policy formulation and implementation, and the credibility of the government's commitment to their policies.

Table 4. Description of variables

Variables	Measures/ Indicators	Source of Data	Hypothesis (Expected Sign)
Dependent Variables			
PriR&DExp	Aggregate Real Private expenditures agricultural R&D in PPP$	Agricultural Science and Technology Indicators (ASTI)	
Independent Variables			
AgGDP	Value of Agriculture GDP Output in PPP$	World Development Indicators (WDI) by the World Bank	+
Openness	Economic Freedom Index	Heritage Foundation with Wall Street Journal (WSJ)	+
IPR	Index of Patent Rights	Ginarte and Park	+
EffectiveGovt	Worldwide Governance Indicators	World Bank	+

Most research on private expenditure on agriculture R&D has utilized the case study method of analysis (Pray and Fuglie, 2001). While there are benefits in using individual case studies to contextualize and isolate explanatory casual mechanisms, a broader perspective that accommodates both variation across time and across countries may elucidate more comprehensive insights. Therefore, this study will employ the use of econometrics to conduct a multi-variable regression on a time-series cross-sectional panel dataset, replicating a similar study done by Alfranca and Huffman among European countries in 2003. The use of econometrics will be useful in quantifying the determinants of private investment in agriculture research given the complexities of the variables.

Model Specification

$$\ln\left(PriR\&DExp_{it}\right) = \beta_1 \ln\left(AgGDP_{it}\right) + \beta_2\, Openness_{it} + \beta_3 IPR_{it} + \beta_4 EffectiveGovt_{it} + Z_i + \alpha_i + U_{it}$$

Where Z_i is the time-invariant effect; α_i is the unobserved individual effect; U_{it} is the error term

To disaggregate the effects of the various variables, two Ordinary Least Square linear regressions (Models 1 and 2) are defined with stepwise increases in addition of variables, as described in Table 6. These two simple model specifications do not take into consideration any error terms, and provide basic analysis of the linear relationship between the independent variables and the dependent variable.

Model 3 takes into account the fixed effects (FE) that may be observed in a panel dataset. The dataset used for this sample is a strongly balanced panel data. Given that the panel data for this study spans across both time and countries, there is a need to account for heterogeneity of the different cases. In particular, given the range of countries included in the study, it is important to consider the heterogeneity across individual countries that can be attributed to their intrinsic time-invariant characteristics. These time-invariant characteristics are confounding variables such as different cultures across countries that impacts both the independent and dependent variable that, if not accounted for, would lend the model towards the omitted variable bias. The legacy of a centrally-planned economy in this set is an example of time-invariant characteristics. The regression analysis will therefore also employ the use of the least square dummy variable (LSDV) fixed effect model, where dummy variables for countries can be included as individual intercepts to control for these country specific differences. The LSDV is an estimation strategy commonly used by researchers such as Huffman and Alfranca (2003). Random effects (RE) are not taken into account for, as this dataset covers a relatively short time period such that using RE would be imprecise (Wooldridge, 2010). A simple test for multicollinearity is conducted (Appendix A) to check for significant correlation between the independent variables, and the results were negative.

The research study has been designed to be rigorous in selection of cases, time period, and standardized treatment of data to minimize any unknown and unaccounted error terms. The 7 Asia-Pacific countries selected represent a range of per capita income levels. This ensures that there is sufficient variation in independent variables among the individual cases to allow for statistically significant results. In addition, having a sizable 47-case dataset ensures that comparison of four independent variable will be statistically significant. The panel dataset begins in 1995 to control for implications on IPR protection resulting from the introduction of the WTO TRIPS agreement. Lastly, converting values for private expenditure spending to the same units and base year enables cross country comparison and generalization to take place.

Given that agriculture is location specific, it will be hard to generalize the findings of this study to other regions of the world, considering this study specifically pertains to producers of tropical agriculture. Thus, findings of this study will be more suited for generalization within the Asia-Pacific region.

Results and Analysis

The mean, standard deviation, minimum and maximum values for all variables used in the study are presented in the Table 5. Middle-upper income countries such as Indonesia, Malaysia and Philippines have relatively high values for level of private expenditure and size of agriculture market, stronger institutions and greater economic openness.

Table 5 Descriptive Statistics

	LnPrEx	LnAg	Openness (on a scale of 0 to 100)	IPR (on a scale of 1 to 5)	Effectiveness (on a scale of -2.5 to 2.5)
Indonesia					
Mean	17.71282	24.19181	56.2	2.20	-0.18
Std Dev	0.050316	0.055409	6.7	0.39	0.36
Min	17.66353	24.12299	48.3	1.56	-0.78
Max	17.79145	24.29365	64.3	2.65	0.19
Malaysia					
Mean	16.87444	23.02031	51.1	3.0	0.5
Std Dev	0.085249	0.053059	7.2	0.2	0.2
Min	16.77562	22.95338	42.0	2.7	0.2
Max	16.97676	23.12507	62.3	3.3	0.7
Philippines					
Mean	17.39899	23.09088	53.4	3.5	0.1
Std Dev	0.103596	0.084654	3.9	0.6	0.1
Min	17.27498	22.98822	47.3	2.6	-0.1
Max	17.61324	23.22782	59.1	4.1	0.3
Laos					
Mean	11.62667	20.44111	25.6	0.0	-0.8
Std Dev	0.28577	0.13043	10.0	0.0	0.7
Min	11.51000	20.25000	0.0	0.0	-1.5
Max	12.21000	20.61000	33.7	0.0	0.2
Vietnam					
Mean	14.0986	22.88886	36.2	2.9	-0.4
Std Dev	0.154724	0.112332	1.0	0.0	0.4
Min	13.91082	22.72255	34.9	2.9	-0.7
Max	14.28551	23.04765	37.0	3.0	0.2
Papua New Guinea					
Mean	14.64851	21.24635	27.6	1.0	-0.3
Std Dev	0.303448	0.050721	20.9	0.6	0.4
Min	14.4033	21.20258	0.0	0.0	-0.7
Max	15.15051	21.33579	48.4	1.5	0.2
Sri Lanka					
Mean	12.03316	21.71456	58.8	3.1	0.1
Std Dev	0.4883	0.040047	2.0	0.0	0.1
Min	11.51293	21.64168	56.7	3.0	0.0
Max	12.61154	21.76464	62.7	3.1	0.3

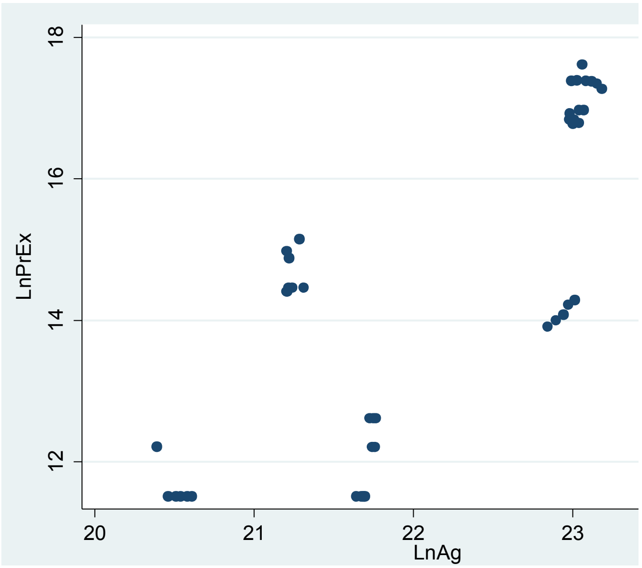

Figure 2 LnAg on LnPrEx

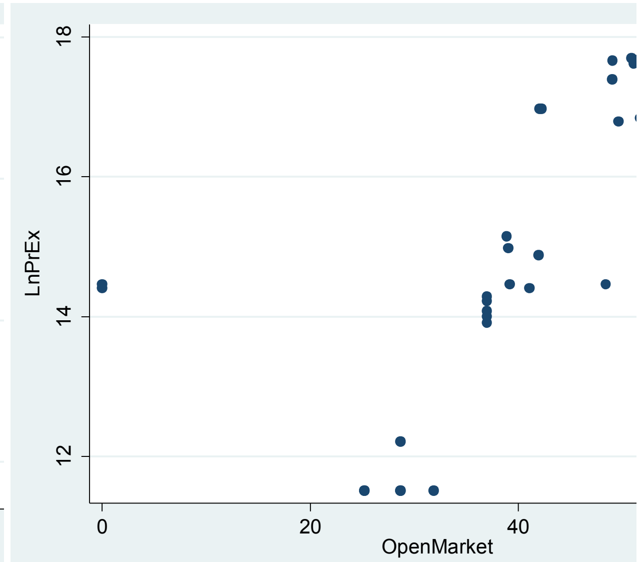

Figure 3 Economic Openness on LnPrEx

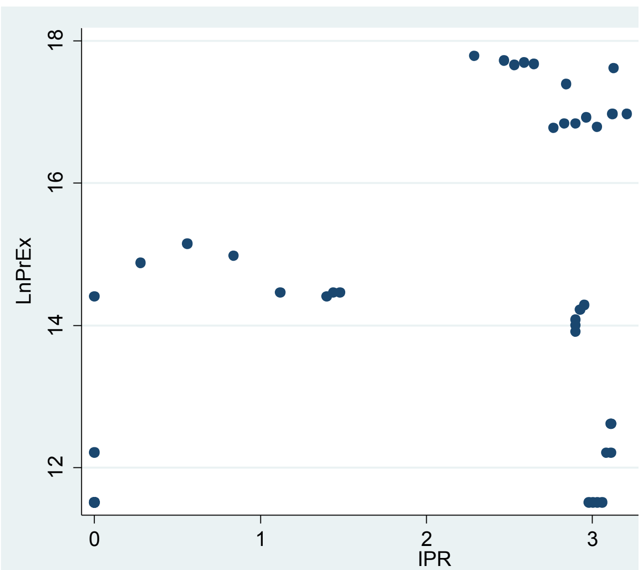

Figure 4 IPR on LnPrEx

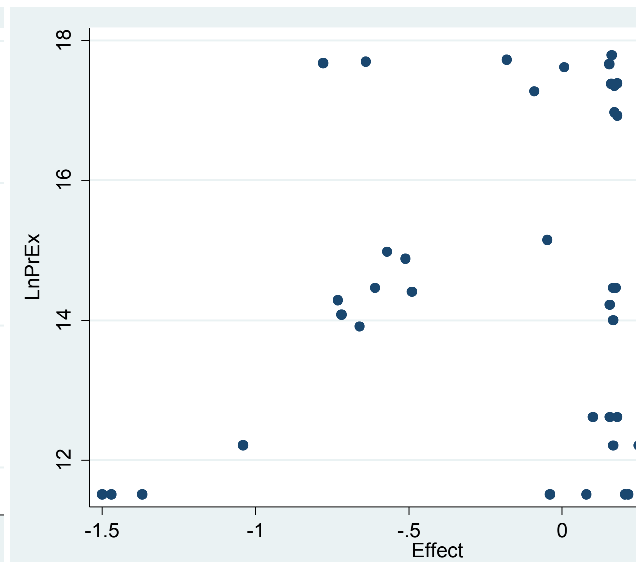

Figure 5 Government Effectiveness on LnPrEx

Table 6 Regression Results

Variable	Model 1	Model 2	Model 3 (Fixed Effects[+])
In(AgGDP)	1.842801*** (0.199)	2.07472*** (0.241)	1.297884 (0.938)
OpenMarket	-0.0280571* (0.015)	-0.0147147 (0.021)	-0.0001856 (0.006)
Effectiveness		0.9591994** (0.446)	-0.0026053 (0.116)
IPR		-.6075922** (0.280)	-0.3581633* (0.180)
Adjusted R-square	0.6692	0.7059	0.9846
# of Observations	47	47	47

*** if p-Value<0.01, ** if p-Value<0.05, *if p-Value<0.1
[+]Country Intercepts not included in table

The results of the ordinary least squares (OLS) estimation can be found in Table 6. All models perform moderately well, with goodness of fit at 67%, 70% and 98% as each model progresses with greater specificity. The trade-off is such that with greater specificity, there is a corresponding decrease in the significance levels of the explanatory variables.

Firstly, with respect to with regards to lnAgGDP (which measures size of agriculture market), for model 1 and 2, this variable has a positive correlation with private investment in R&D at a significance level of 1%. The results imply that a 1% increase in size of the agriculture market, there is a 1.8% increase or 2.07% increase in private R&D investment depending on the model specification. The strong linear relationship between market size and level of private investment can also be induced from the scatterplot in Figure 3. This finding helps to explain the disparity in private investment across countries. As seen in Table 5, middle-upper income countries like Indonesia, Malaysia and Philippines which have larger agricultural markets, also have higher levels of private investment in agricultural R&D. However, when country specific effects are taken into consideration in Model 3, there is no statistically significant relationship. This is likely because, even though the size of AgGDP increases along with the increase in GDP/Capita over time (Table 1), especially for countries like Sri Lanka, Vietnam and Malaysia (Figure 2), the limited variance across a short period of time limits the model's ability to derive statistically significant relationships.

Nevertheless, out of all four independent variables, the size of the coefficient for lnAgGDP is the largest in all three models. This finding indicates that market size plays a relatively more prominent role in determining levels of private sector involvement in research. The findings regarding market size strongly corroborate with earlier studies such as those done by Huffman and Alfranca (2003) for the EU market, and by Pray and Nagarajan (2014) for the Indian market, supporting the notion that economic incentives play an instrumental role in attracting private investment.

Similarly, the Government Effectiveness variable displayed coefficients as hypothesized. This variable has a positive correlation with private investment in R&D at a significant level of 5% in Model 2, but was not statistically significant in Model 3. The results indicate that a unit increase in the Index of Government Effectiveness will increase private investment in R&D by around 1%. This findings also support earlier studies by Huffman and Alfranca (2003), which found a positive relationship between contract enforcement and private investment, and a negative relationship between bureaucratic delays and private investment. Qaim and Traxler (2005) also presented evidence that expected efficiency in technology approval procedures positively influenced private investment. The notion that an effective government is instrumental in attracting private investment in agriculture research is increasingly relevant in Asia, as governmental agencies are taking on key roles in coordinating research agendas across public and private sector.

The other two variables, OpenMarket and IPR, have coefficients that contradict the original hypothesis. For OpenMarket, which measures the openness of the economy, the variable had a statistically significant negative relationship at 10% level only for Model 1. The results imply that a unit increase in the Open Market Index will decrease private R&D expenditure by 0.02%. While this contradicts the initial hypothesis, this finding is also supported by earlier studies, (Huffman and Alfranca, 2003). Huffman and Alfranca explained their findings by suggesting that because agriculture technologies have to be adapted to local climate and conditions, an economic climate biased towards domestic firms relative to foreign firms is more advantageous to local private agricultural R&D investment. This builds on the work that Evenson and Westphal (1995) and Keller (2002) have done on technological diffusion. They argue that domestic innovation capacity, a sum of local public and private R&D programs, is needed before countries are able to adapt foreign technologies. Another explanation for this negative coefficient for Openness could be the presence of outliers. As seen in Figure 4, there is a cluster of scatter points that shows high openness yet low levels of private investment. These scatter points represent Sri Lanka, a relatively open country that faced major political instability and ethnic wars in the early 1990s that deprived the country of investment (De Silva *et al*, 2013). When Model 3 accounts for the fixed effects across countries, the coefficient of OpenMarket become statistically insignificant.

The negative relationship between strength of IPR regime and private sector involvement is another finding at odds with the original hypothesis. For IPR, the negative coefficient was significant in both Model 2 and 3 at a 5% level and 1% level respectively. The results indicate that a unit increase in the Index of Patent Rights will decrease private expenditure in R&D by 0.6% and 0.35% for Model 2 and 3 respectively. This findings appears to be at odds with the literature (Pray and Fuglie, 2001) which assert that higher appropriability of returns will increase private research. This finding also contradicts the results of Huffman and Alfranca (2003), who found positive coefficients for variables such as Contract Enforcement and Patent Rights, suggesting the importance of supportive institutions that protect property rights in attracting more private sector investment.

One plausible explanation for this discrepancy is the difference in context between previous studies and this study. Huffman and Alfranca (2003) focused their study on European countries from the developed world, whereas this current study is the first of its kind that focuses on developing countries in Asia. This sample set of this study also accounts for states under authoritarian rule in transition, which are different from the Western democracies in previous studies. As mentioned earlier in the literature review, the impact of IPR is not uniform across countries of different income and standards of development. Chen and Thitima (2004) found empirical evidence that at low levels of income and corresponding low levels of technological ability, countries tend to weaken their IPR regime, which biases against foreign technology and benefits domestic firms, to allow for learning by imitation. In her study of developing countries and impact of IPR, Payumo (2011) also found a negative association between stronger IPR on living organisms as a result of TRIPS and a decline in agricultural development.

Another reason why the coefficient of IPR did not read as planned was because IPR only captures one aspect of appropriability, the legal mechanism to protect property rights. As mentioned in the literature review, however, there are multiple dimensions of appropriability, such as biological properties of hybrid seeds, and industry concentration of monopoly power, which this study did not account for. Other studies (Pray and Nagarajan, 2014; Spielman *et al*, 2014) which took into consideration these other dimensions of appropriability such as firm concentration of the industry and biological properties of hybrid crops, were able to demonstrate that in the presence of stronger appropriability, there are stronger incentives for private firms to invest in agricultural R&D.

This discussion on appropriability also helps to shed light on the interesting dynamic between openness and IPR strength. Currently the coefficients on both imply that a relatively closed economy and weak IPR regime can still attract private investment in agriculture R&D. The openness of a country's economy is inversely related to the level of control the government has in intervening in the market. A relatively-closed economy is one where the government or state-owned enterprises have a monopoly over the local market and foreign companies are at a disadvantages. This allows domestic firms to appropriate their returns to investment without needing strong legal protection. This can help explain the performance of Vietnam. As shown in Table 5, although Vietnam may have a weaker level of IPR protection and a smaller openness index than Sri Lanka, Vietnam has a higher level of private investment in R&D.

Overall, findings suggest the predominance of strong markets in attracting private investment in agriculture R&D. In addition, the role that the government plays in ensuring institutions are effective is also key in positively influencing how private actors perceive incentives to participate in the economy. The findings around Openness and IPR strength indicate that a minimum standard of domestic technological capacity is required before developing countries can benefit from increased foreign private investment.

The biggest limitation in this study is the narrow sample size, which restricts the robustness of the model and tempers the ability of the model to get statistically significant readings. As a result, there is a limit to the specificity of the model, such that the model may lend itself to the omitted variable bias. This prevents the model from controlling for other supply-side determinants of private investment, such as the interaction between public and private research systems, domestic supply of human capital and skilled labor, government subsidies and R&D tax credits, and cost of technological innovation.

In addition, the short time period for which the data accounts for limits the lack of variance in data within a country across time. The lack of variance is further confounded by the need to linearly interpolate variables like the IPR index to replace missing data. Further studies should be completed with the inclusion of a larger sample set over a longer period of time and with the consideration of multiple regions aside from Asia.

Another theoretical limitation of this study is the problem of endogeneity and reverse causality in studying intuitional policy over range of income levels. Rodrik (2004) highlights the problem empirical studies face in being unable to distinguish whether improvements in property rights and rule of law are independent of income (and in this model, the size of agriculture market), and not simply consequence of higher incomes. A more robust model can be specified in future studies to take into consideration time lags as an instrument to separate the cause and the effect over time.

Other areas for future study include investigating the disaggregate effects of economic openness and strength of IPR regime on domestic versus foreign innovation, and also exploring how the determinants of private sector investment vary across different agriculture markets along the value chain.

Conclusions

This research has focused on the analysis of the complex interactions between economic incentives and intuitional factors and their influence on private R&D investment in agriculture in developing countries in Asia. With regards to economic incentives, the empirical findings show that private sector R&D investment responds favorably to size of the country's agriculture market. However, it does not respond the same way to the openness of the economic market because agriculture technologies need to be localized. The size of the country's agriculture market is shown to have the biggest effect on private sector R&D, indicating the importance of market demand in attracting R&D investment.

The findings showed that while government effectiveness matters, strength of IPR protection had a negative impact on private sector R&D investment, especially in developing countries with low technological capabilities.

When the empirical findings are seen in the light of the recent developments in the Asia-Pacific region, it becomes evident that the prerequisite conditions for private sector investment possess a progressive ordering of importance. This supports the argument that Pray and Fuglie (2001) makes, that sequencing of policies is necessary for effective private research development. Consequently, policymakers must understand that some conditions have primacy in building an environment for robust private-sector investment in agriculture R&D.

Placing undue emphasis on strengthening IPR regime in the absence of strong domestic market for agriculture R&D outputs will not effectively stimulate R&D activities. Rather, economic reforms and liberalization of the market, as witnessed by countries in Asia, are needed first to secure an established market among farmers and producers for private firms to supply technology to. Policies that incentivize the development of agriculture markets and reduce the distortion of government intervention are key. Institutions such as strong IPR regimes and effective governance can complement economic growth when these conditions are met. In the long run, a flourishing private sector requires adequate regulatory protection for firms to protect their innovation. Additionally, private sector firms will also benefit from working in collaboration with a complementary public research system.

This discussion of economic incentives and institutional quality in agriculture research ties in with the larger macro-perspective of economic growth and development. Endogenous growth theorists and developmental economists like Acemoglu (2001), Rodrik and Rodríguez (2000) also put forth the argument that institutions that provide market-oriented incentives and protect property rights help catalyze economic growth. However, they are also cognizant of the need for prescriptive and contextualized country diagnostics in determining effective policies. In the case of developing countries that do not have all the necessary preconditions for private sector involvement, embracing openness and harmonization with international IPR frameworks may result in the decline in economic performance. Policymakers in developing countries need to understand that strategic priorities differ among countries at different stages of economic growth. Ultimately, they should prioritize the importance of domestic capacity building, in terms of research capacity, secure markets and national innovation system, to accompany their policy reforms.

In summary, agriculture R&D and innovation are instrumental in helping developing countries to achieve agricultural productivity and growth. The private sector plays an important role in catalyzing innovation and development. Realizing the benefits of greater private sector involvement requires the right market conditions, complementary institutional design and public support. By undertaking suitable and germane measures to stimulate private investment, in a manner that is contextualized to location-specific constraints, developing countries will be able to attract sustainable sources of financing to nourish the growth in agriculture research.

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Appendix

Test for Multi-collinearity

To ensure that multi-collinearity is not negatively impacting the regression analysis and interfering with the estimates of the coefficient, tests for multi-collinearity were carried out. In the model used for analysis for this study, although variables measuring institutional factors, such as openness of market, government effectiveness, and strength of IPR protection, may be conceptually independent of each other, it might be the case that empirically these values are in close relation with each other, and may cause the problem of multi-collinearity to arise. If multi-collinearity is indeed an issue in this model, it may distort the model and interfere with the signs and standard error of coefficients. A formal method to test for multi-collinearity is the use of the variation inflation test (VIF), which is provided in Stata, and results are shown in Table 7. The results indicate that the model did not have issues with multi-collinearity as all variance inflation factors are below 10.

Table 7 Test for Multi-Collinearity

Variable	**VIF**	**1/VIF**
In(AgGDP)	4.59	0.217782
IPR	3.55	0.281997
Openness	2.44	0.409423
EffectiveGovt	1.81	0.552166
Mean VIF	**2.97**	