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Agricultural policy and the role of intermediate institutions in production capabilities transformation: Fundación Chile and Embrapa in action

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Abstract

The paper documents in great detail a large number of policies and institutions targeting production capabilities transformation in agriculture ? not just in today?s developing and transition countries in the last 60 years, but also in today?s rich countries in the late nineteenth and early twentieth centuries. In order to fully understand policy rationales, functions and mechanisms our analysis addresses and disentangles a number of structural specificities characterising agricultural production and learning. Among the broad set of agricultural input and output policies, the paper focuses on a selection of factor inputs policies as well as agricultural marketing and processing measures. Historically a significant number of these policies and respective functions have been performed in different combinations by various types of intermediate institutions. These institutions are called intermediate as they play a critical intermediary role between R&D, education, markets and in-farm agricultural production. They also bridge and transfer knowledge, technical solutions and innovations across different sectors and, thus, facilitate various forms of intersectoral learning. The rationales, functions and functioning of intermediate institutions are detailed with two in depth case studies of Fundación Chile and Embrapa in Brazil. The paper concludes by sketching a number of policy lessons for rethinking public policy in agriculture and stresses the critical role of intermediate institutions within a new agricultural policy mix.

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1. INTRODUCTION

It is acknowledged that agricultural development fuels economic growth and is crucial to poverty alleviation and food security. However, in the last 25 years or so, the agricultural sector experienced relatively sluggish development in a number of developing economies. Among the factors associated with agriculture's poor performance, agricultural policy and institutional frameworks are of particular relevance because they affect agricultural performance most directly and also are controllable to a certain extent by policy-makers.

Many (although definitely not all) of the policy and institutional frameworks adopted by developing countries during the period have followed the so-called "Washington Consensus", which emphasized the role of market forces in the economy as the main mechanism for resource allocation. The prescriptions emanating from these frameworks had emphasized the need to redefine the role of the public sector in promoting and regulating free and competitive markets, rather than in directly providing and subsidizing goods and services needed for agricultural development.

However, the withdrawal of the state from a developmental role has negatively affected investment in public goods (e.g. agricultural research, education, extension and infrastructure), which has reduced agricultural productivity. In addition, market-oriented reforms of financial institutions have left agriculture with even less access to credit than before. Trade liberalization has led to increased competition from imports, which has threatened the livelihoods of many farmers. A simultaneous push for agricultural exports in many countries that specialize in the same products often has resulted in falling prices and export earnings. Fortunately, these problems are now beginning to be recognized by even the traditional advocates of the Washington Consensus (WC), although it remains to be seen whether this will lead to a real shift in policy paradigm (World Bank, 2008).

This paper aims at addressing these concerns by drawing lessons from the history of agricultural policy – not just in today's developing and transition countries in the last 60 years, but also in today's rich countries in the late nineteenth and early twentieth centuries. Specifically, the paper documents in great detail a large number of policies and institutions targeting production capabilities transformation in agriculture. In order to fully understand policy rationales, functions and mechanisms our analysis starts by disentangling a number of structural specificities characterising agricultural production and learning.

Among the broad set of agricultural input and output policies (Chang 2009), the paper then focuses on the rationales, functions and mechanisms behind *factor inputs policies* mainly related to production capabilities development as well as *agricultural marketing and processing*. Historically a significant number of these policies (and respective functions) have been implemented (performed) in different combinations by various types of *intermediate*

institutions. These institutions are called intermediate as they play a critical intermediary role between R&D, education, markets and in-farm agricultural production. They also bridge and transfer knowledge, technical solutions and innovations across different sectors and, thus, facilitate various forms of intersectoral learning.
The rationales, functions and functioning of intermediate institutions are detailed in the paper with two in depth case studies of Fundación Chile and Embrapa in Brazil. Both cases highlight the crucial role played by intermediate institutions in fostering the development/adaptation of traditional agricultural techniques, but also in innovating and diffusing them across different regions and sectors.

The paper concludes by sketching a number of policy lessons for rethinking public policy in agriculture and stresses the critical role of intermediate institutions within a new agricultural policy mix.

2. AGRICULTURE: PRODUCTION, LEARNING AND POLICY

There are surprising similarities in terms of the role that agriculture plays in different economies at similar stages of economic development and the problems they face in the agricultural sector (Koning, 2007; Chang, 2011). Today's rich countries all grappled with issues very similar to those with which today's developing countries are struggling – landlessness, fragmentation of holdings, lack of irrigation and other rural infrastructure, backward technologies, limited availability of credit to small-scale farmers, excessive price fluctuations, limited availability and poor quality of farm inputs (especially fertilizers), poor warehousing and marketing facilities (which often force farmers to sell at the wrong time and wrong prices), food insecurity and trade shocks. Given the similarities of the problems, it is also not surprising that the policies and institutional solutions devised by the farmers and governments of those countries were very similar to what today's developing countries may contemplate.

Before revising such policies and institutional solutions, the following three sections analyse respectively: (i) the structural problems characterising agricultural production; (ii) the different learning trajectories through which production capabilities are transformed and, (iii) finally, the rationales behind agricultural policies. Disentangling the relationship between agricultural production, learning and policy is a fundamental step for understanding factors inputs policy (see section 3) and the specific combinations of functions that intermediate institutions can perform.

2.1 AGRICULTURAL PRODUCTION

The fundamental structural feature of the agricultural sector is that its output results from three distinct (although interdependent) processes of production: agricultural work, biological production and biological reproduction (Andreoni, 2011).

Agricultural work consists of a set of interrelated tasks such as ploughing, planting, fertilising, inspecting, harvesting, storing and transporting. Each of these tasks is performed by coordinating productive capabilities embedded in workers and various 'cooperation instruments' (e.g. mechanical equipment, engines and animals). Cooperation instruments complement and empower workers by (i) enhancing the performance of particular tasks in specific ways (e.g. increasing accuracy, strength or intensity); (ii) allowing different tasks to be executed at the same time; finally, (iii) increasing the speed of production operations or reducing idle times.

Biological production occurs in land and consists of processes of transformation of biological materials triggered and fostered at appropriate intervals by agricultural work. In order for land to perform a specific biological production process agricultural work and flow inputs are both required.

Finally *biological reproduction* is necessary to restore the land capacity's to perform biological production. One of the most effective answers to these agronomic constraints has been the development of rotation schemes. Historically the introduction of these schemes actually induced technological advances in agricultural techniques and tasks organisation such as the introduction of 'inserted crops' and 'associated crops'.

'Crop-growing techniques' are by definition context-dependent as a result of land's biological differences, environmental conditions and finally divergent socio-cultural and economic contexts. In the design of a crop-growing technique farmers have to address two fundamental constraints and one major challenge (Andreoni, 2011):

(i) *Time constraint*: arranging agricultural production in 'seasonal time';

(ii) *Scale constraint*: reaching the most appropriate scale of production and mechanisation;

(iii) *Productivity challenge*: improving agricultural work by changing crop-growing techniques, increasing the productivity of biological production and making biological reproduction faster.

From the moment of the 'First Green Revolution' (which occurred in the period 1879-1914 according to van Zanden, 1991) the agricultural sector has undergone a tremendous process of technological and organisational change which allowed farmers to address such constraints and challenges. Different patterns have been followed which focus on mechanical, biological, chemical, agronomic, biotechnological and informational innovations (Pardey, Alston and Ruttan, 2010). The transformations have been triggered by in-farm learning, but also processes of technological change at the intersectoral level – i.e. *intersectoral learning* – as well as processes of *technology transfer* at the intrasectoral level (Andreoni, 2011).

2.2 INTERSECTORAL LEARNING AND TECHNOLOGY TRANSFER

As Rosenberg (1979:26-27) stresses in his analysis of technological interdependence in the American economy 'inventions hardly even function in isolation'. Instead they "depend upon one another and interact with one another in ways which are not apparent". As a result the productivity of one technology or organisational innovation depends on the availability of complementary innovations.

Complementarities have been crucial focusing devices in the process of choice and exploration of new techniques across history. Static and dynamic complementarities, as well as similarities and indivisibilities are essential focusing devices for activating compulsive sequences of technological change as well as for *discovering new productive possibilities* (Andreoni, 2013).

Many stylised facts in the history of agrarian change support the existence of these processes of learning in the agricultural sector. For example, the introduction in California of a new harvesting technique was accompanied by the need to introduce a new complementary tomato variety. Another documented case can be found in the Punjab region where, during the 'Green Revolution', farmers realised how the full exploitation of new HYVs was constrained by irrigation and fertilisation practices. The intensification of the latter, in turn induced farmers to focus their attention on discovering more adequate crop-growing techniques and the introduction of new organisational forms.

A further example can be found in the early nineteenth century US agricultural sector. Before tractors were introduced, John Deere, a farmer from the Illinois, invented the steel plough. Traditional wood ploughs were unable to deal with the rich soil of the Mid-West and kept breaking. In turn, the introduction of the steel plough triggered new complementary discoveries. The John Deere Company was able to 'internalise' this process of learning and qualitative improvement of mechanical tools by establishing its own research and development infrastructure. As a result, it became the world's leading manufacturing firm specialised in innovative mechanical agricultural equipment.

As this last case shows, the process of structural learning in the agricultural sector has gradually developed an intersectoral character. In other words it has moved 'from the farm to the firm' and then to other science-based organisations. In this respect, there is strong historical evidence that the emergence of technical and organisational innovations in agriculture have been triggered by the expansion of metallurgic, mechanical, biotechnological and energy industries (van Zanden, 1991). Indeed innovations in power generation and, in turn, the cost of transportation have been identified by Rosenberg (1979) as the main drivers of increasing productivity in American agriculture.

These examples show how an innovation arising from one industry can not only reduce the cost in the receiving industry but also open up a series of opportunities for change in products and processes. *Intersectoral learning* is then a dynamic process of interlocking and mutually reinforcing technological developments that link the innovative patterns of two or more sectors in a relationship of complementarity (Andreoni, 2011). As a result of this process "many of the benefits of increased productivity flowing from an innovation are captured in industries *other* than the one in which the innovation was made" (Rosenberg, 1979:41).

With the blurring of intersectoral interfaces and the increasing importance of marketing and processing techniques in modern agriculture, new spaces for processes of intersectoral learning are emerging (FAO, et al. 2009). However, the developments of agro-processing industries as well as the activation of processes of intersectoral learning are becoming increasingly dependent on the development and transfer of technological/production capabilities in the agricultural sector.

Technology transfer has been one of the main drivers of agrarian change both during the 'first' green revolution' in the late nineteenth century (van Zanden, 1991) and during the 'Green revolution' proper in the middle of the twentieth century (Byerlee and Fischer, 2002). According to Hayami and Ruttan (1973) technology transfer occurs in three main phases. During the first stage (*material transfer*) new seeds, plants, animals and machines are imported and utilised without any attempt to 'naturalise' them. As soon as adaptability problems become evident farmers, as well as public actors, start to import blueprints, designs and formulae to decrypt the new 'crop-growing technique'. This is known as the *design phase*. At the end of the process of technology transfer, that is, the *capacity transfer* phase, farmers and public actors start attracting foreign experts, creating specific research institutions, adapting foreign technologies and, finally, experiencing processes of intersectoral learning.

The historical and empirical record (Kay 2009; Chang 2009 and 2009b; Andreoni 2011) clearly shows how the speed of technological transfer and adaptation, and the benefits that technologies can generate, depends strictly on the intensity of efforts made by countries to develop their production capabilities. Specific public policies and institutional tools are required to allow endogenous processes of technological capabilities building as well as to trigger processes of intersectoral learning.

2.3 AGRICULTURAL POLICY RATIONALES

Like all other economic sectors, agriculture requires better technologies to increase productivity. Of course, farmers have always innovated technologically, including through selective breeding and making improvements in agricultural implements. However, from the nineteenth century, technological improvements in agriculture have become more systematic and scientifically-based, making it very difficult, if not totally impossible, for individual farmers to conduct them on their own. Deliberate and organized research is needed now to produce better technologies in agriculture.

Once research produces new technologies, they need to be passed on to farmers. This process requires many institutions and organizations to demonstrate the value of the new technologies and teach the farmers how to use them; these are collectively called "extension services". The farmers need to be educated so they can better apply the technologies and also engage in incremental innovations. In the process, farmers need to be exposed to information that will raise their awareness about new technological opportunities and shifting demand patterns. Therefore, a whole set of institutions and organizations have come to be needed for technological improvements in agriculture.

Due to the public goods nature of knowledge, the market tends to under-invest in the generation of new knowledge. This justifies public intervention – either direct state provision or subsidization. Increasing costs of producing and disseminating knowledge have made public involvement even more necessary, because many of these activities are moving beyond the reach of individual farmers or even farmer cooperatives. Therefore, public intervention in providing research, extension, education and information has become more important (Chang, 2011).

The WC recognizes the problems involved in producing and extending new agricultural technologies through the market mechanism. However, it believes that market failures that justify state intervention in providing knowledge are not very serious and it has therefore strongly promoted involvement of the private sector in providing knowledge. The WC has always emphasized budget balancing, which leads to cuts in expenditures especially in agriculture given its intrinsic weaknesses.

When countries followed the WC and privatized or liberalized providing knowledge in agriculture, the results have been disappointing, to put it mildly. In many cases, there simply were not enough private firms to fill the gap left by the state's departure in these activities, especially in research and extension. For example, in Mexico, WC policies have resulted in insufficient provision of agricultural knowledge and other public goods needed in the sector, such as infrastructure and safety standards. These examples contrast with the fantastic successes that publicly-led (although not entirely publicly-provided) research and extension services have had in countries like the United States and Japan. The next section focuses on a historical analysis of factor inputs policies for production capabilities transformation in agriculture.

3. FACTOR INPUTS POLICIES FOR PRODUCTION CAPABILITIES TRANSFORMATION IN AGRICULTURE

3.1 Agricultural Research

Technology in agriculture is a public good. Its use by those who did not pay for it is difficult to prevent (this is known as non-excludability) and therefore it is undersupplied by the market. However, there is an added difficulty in producing agricultural technologies. Production of knowledge, even if the use of the new knowledge by non-payers can be prevented (e.g. through a patent system), often requires substantial investments. This can be a crucial obstacle to knowledge production in an agricultural sector dominated by small scale farmers, which we find in most developing countries. As a result, governments throughout history intent on improving agricultural productivity have been involved in conducting or at least subsidizing agricultural research.

Germany established the first endowed public agricultural research institute in the world in Mockem, Saxony in 1852. Other European countries that have been most successful in agriculture, such as Denmark and the Netherlands, also heavily promoted agricultural research (Ingersent & Rayner, 1999, p. 42-44). In Denmark, the Royal Agricultural Society (established in 1769) started from 1857 to organize “laboratory work of interest to farmers” while in the Netherlands, in addition to the experimental station at the agricultural university in Wageningen, five additional experimental stations were set up by the end of the nineteenth century. In contrast, the lack of effective public research in agriculture partly contributed to the relatively low productivity growth of French agriculture during this period.

At least since the 1860s, the United States has provided a huge amount of public research and development (R&D) in agriculture, directly (e.g. federal agricultural research labs and experiment stations) and indirectly (e.g. through establishing land grant colleges in 1862, which were obliged to provide agricultural research)

In most developing countries today, there has been clear recognition of the importance of public intervention in agricultural research. While most people consider Chile to be a free-market success story, even that country has had a very strong policy towards agricultural research that has been getting even stronger (see more in section 5.1). However, lack of resources has severely constrained public support for agricultural research in many developing countries. Even when they have financial resources for agriculture, governments in poor countries tend to use them on things that will have more immediate impacts, such as fertilizer subsidies and marketing expenditures.

Of course, spending more money on R&D does not necessarily guarantee better results. For one thing, even when the money is ostensibly used for R&D, it is often in practice spent on recurrent expenditures (such as wages and supplies) rather than on genuine investment, as in the case of Ethiopia. Moreover, research could be poorly organized. For example, in Hungary under socialism, considerable resources were put into agricultural R&D, but the results were less than impressive partly because they were not mainly driven by consumer demands and partly because there was little international cooperation. Similar problems were observed in Ghana, including the lack of coordination among research projects conducted by universities and other academically-oriented entities, the de-linking of research from the real world and the absence of links with extension services (Chang 2011).

Interestingly, India’s experience shows that financial constraints need not totally bind. Despite spending relatively small amounts of resources in agricultural R&D, India has managed one of the most comprehensive and successful publicly-organized agricultural research programmes in the developing world, not least because it deliberately learned from successful historical cases like the United States.

3.2 Agricultural extension services and information sharing

Because they cannot be easily codified and written in instruction manuals, all technologies require technical support to some degree in their initial phases of dissemination (e.g. demonstrations, teaching how to use it, troubleshooting). However, technical support is particularly important in agriculture because it is necessary to adapt technology to the variations in climate and soil conditions in different localities. Therefore, agricultural technology transfer requires the presence of agents who understand the technologies and the local conditions; these “extension services” became particularly important in the nineteenth century with the rise of scientific methods in agriculture.

The idea of extension services started in the United Kingdom in 1843 (Rothamsted), but Germany was the pioneer in widely implementing the idea. According to van Zanden (1991), “although the first agricultural experimental station had been set up in Rothamsted in 1843, it was the Germans who set the example in the organization of a more or less nationwide system of agricultural research and extension services, largely sponsored by the state” (p. 237). In contrast, Britain and France, despite their relatively advanced bases of manpower, did not really start agricultural extension services until World War I, which is one of the reasons why countries like Germany and Denmark, which provided better extension services, caught up during this period in terms of agricultural productivity.

Like Germany, Sweden and Denmark used itinerant instructors to spread better agricultural technologies. In the Netherlands, a state extension service was developed in the late nineteenth century, alongside agricultural education (Ingersent & Rayner, 1999, p. 45). The government of the Netherlands introduced extension services in 1890, first in crops and then in horticulture and dairy production. The United States also took extension services very seriously. Economically more advanced states, like New York, set up extension services in the form of a farmers’ institute for education and demonstrations in the late nineteenth century (Colman, 1965, p. 43). Japan took the idea of agricultural extension even further – it had a much tighter link between research and extension than other countries and had an extension worker for every village (which typically had 100 or fewer farming households) (FAO, 1966, p. 28).

In today’s rich countries during the late nineteenth and early twentieth centuries, one common method of providing better information to farmers alongside extension services was organizing agricultural fairs, where prizes were given to those who produced high-quality outputs and exhibitions presented new agricultural implements and inputs. Agricultural fairs in the United States are famous, but other countries (e.g. Japan and the Netherlands) also used them actively (FAO, 1966, p. 16).

Unfortunately, with few exceptions, extension services and information sharing in many developing countries have been of poor quality. In many countries, they have been underfunded and poorly coordinated with agricultural research. During the 1980s and 1990s when the WC was dominant, the few remaining extension services suffered from severe funding cuts (including cuts in salaries for extension workers, which made many qualified people leave the service) and diminishing affordability for small-scale farmers because the subsidy elements were cut or even totally eliminated.

3.3 Skills for agricultural work

Public intervention in educating farmers (either through direct provision or subsidies) has played a crucial role in all agricultural success stories throughout history. General rural education is the basis for improving farmers’ productive capabilities. Denmark was a pioneer in this regard. It introduced eight-year compulsory schooling countrywide (between the ages of 6 and 14), following the 1814 Elementary Education Act. Since the 1840s, the Danish government has spread secondary education in the rural areas by encouraging Folk High Schools. Germany also introduced compulsory basic education in the late nineteenth century (Tracy, 1989, p. 103-111).

Today most developing countries recognize that education, including in rural areas, is important. For example, Viet Nam's Government has contributed considerably to the country's agricultural development through continued investment in rural education (Viet Nam case study). However, general education is not enough for agricultural development. Farmers often need specialized knowledge in agriculture to create a productive agricultural sector. In many of today's rich countries, agriculture was taught in general secondary schools in rural areas (e.g. in New York state in the United States) (Colman, 1965, p. 49). Many of them also established specialized agricultural secondary schools and they tried to improve farmers' knowledge even after they left school. In the late nineteenth century, agricultural schools were set up in Denmark, Japan, Sweden and the Netherlands (Chang, 2011).

In many of these countries, the government went further and promoted agricultural studies in universities. The most striking example in this regard is the United States. After the Morrill Act of 1862, the United States set up land grant colleges, which were mandated to promote agricultural teaching and research (Ingersent & Rayner, 1999**,** p. 43). All land grant colleges were given public land in their states or the rights to public land in other states (if there was insufficient public land in their own states) to finance themselves. In New York, the agricultural college of a private university (Cornell University) was given a land grant and thus effectively "nationalized" (Coleman, 1965, p. 44).

Specialist agricultural education does not receive the same kind of emphasis at the secondary and tertiary levels in today's developing countries, largely because of the excessive emphasis that the WC has placed on primary education. For example in Ghana, the austerity measures taken during the Economic Reform Programme (ERP), implemented in 1983, led to the collapse of the farm institutes that were training young farmers and the agricultural colleges that were training extension staff. In Ukraine, the state's withdrawal during the transition period led to a collapse in agricultural education and training.

3.4 Physical inputs and production technologies infrastructures

Government involvement is needed in providing key physical inputs and production technologies infrastructures to agriculture for a number of reasons. First, some of the inputs, such as canal irrigation and transport infrastructure (e.g. roads, railways and, increasingly, airports in countries that export horticultural products) have public goods characteristics and they will be underprovided if left entirely to the private sector. Moreover, in organizing large-scale irrigation projects (e.g. canal irrigation), the government's ability to override individual or sectional interests and/or to rearrange property rights is particularly important. Otherwise the transaction costs of organizing such projects might be prohibitive.

In certain circumstances public-private partnerships, like the one pioneered by Sweden for its irrigation development, are viable alternatives. In Sweden, this cooperative relationship later provided a template for developing other infrastructure, such as railways, telegraph, telephone and hydroelectric power in the late nineteenth and early twentieth centuries (Chang, 2002, p.40).

In the developing world, between independence and the Green Revolution, the Indian state financed, built, and managed all major irrigation projects and most medium-sized ones. The productivity of these projects was relatively limited before the Green Revolution due to the absence of water-responsive seeds; however, they enhanced the equality of access to water across regions and classes.

Certain inputs, such as deep-well irrigation and agricultural machinery, may not be public goods but providing them requires significant investments that are beyond the financial means of most farmers. If small-scale farmers with little capital are to use these inputs, they would need state support such as the ability to lease state-owned machines and equipment, state-mediated access to credit to purchase the inputs or subsidies to lower the prices. Even if the farmers have the money to buy these inputs, it may be necessary for the government to maintain product quality standards, as consumers have difficulties ascertaining the quality of inputs even after use.

Better seeds are critical in raising agricultural productivity. The effectiveness of some other modern inputs also critically depends on the nature of seeds. For example, the effectiveness of better irrigation and increased fertilizer use was enhanced during the Green Revolution, because the new seeds were highly responsive to water and fertilizer. Better seeds have been developed in all of today’s rich countries, often through public research. For example, the Japanese Government organized and financed an elaborate multi-layered system of seed development and dissemination, which enabled the country to develop seed varieties that suited different local conditions.

Public interventions in the production and distribution of seeds have been common in today’s developing countries. The Philippines Government and the Mexican Government joined forces with international non-profit foundations (i.e. Ford and Rockefeller) to develop high-yielding varieties of rice and wheat. The Egyptian Government has also been deeply involved in the development, multiplication, importation and distribution of seeds.

In many of today’s rich countries, governments subsidized fertilizers and/or promoted their use through extension services in the past. In the long run, fertilizers are likely to be even more successful if they are combined with fertilizer-responsive crop varieties, as seen in Japan and Korea or in India (Chang, 2011).

Another fertilizer policy that is not widely discussed despite its potential importance is public regulation of fertilizer quality. Because farmers cannot know the quality of fertilizer before its use and because its quality cannot be easily ascertained even after its use (because there are too many intervening variables), there is great opportunity for fraud in the fertilizer market, especially when the producers do not have recognizable brand names.

Given this, some governments tried to impose quality standards or even supply fertilizer themselves, in an attempt to assure quality. For example, the New York State Government imposed quality standards on fertilizers in the late nineteenth century (Colman, 1965, p. 42), while Korea produced fertilizer in state-owned companies.

3.5 Marketing, processing and quality improvements

Producing greater quantities of raw agricultural products by using better inputs is important, but farmers' final incomes critically depend on how products are processed and how and where they are marketed.

One important area of public intervention in agricultural marketing is providing and/or subsidizing public goods that are necessary if the products are to be sold in higher income areas. These public goods include transport infrastructure (e.g. roads, ports and, increasingly, airports), market information (e.g. amount demanded, prevailing tastes in the destination markets) and branding of products by variety (e.g. Blue Mountain coffee) or for export by the whole country (e.g. Colombian coffee). These inputs, of course, can also be provided by producer associations or farmer cooperatives with the government intervening indirectly by providing legal and financial help for those organizations. There are finally other inputs into marketing that are not public goods, but which may be costly to provide (e.g. warehouses, cold storage or testing facilities for food sanitation and safety).

In addition to better marketing, better processing of agricultural products is very important for raising rural incomes. Relatively simple processing of agricultural raw materials can add significant value and thus promote industrialization and overall economic development. Developing agroprocessing industries is also important in creating more lucrative, rural, nonfarm employment, which is particularly helpful for those who have little or no land and therefore rely mainly on employment for their livelihoods.

In the history of today's rich countries, Denmark may be the most successful example of a country developing an agroprocessing industry. In the late nineteenth century, Denmark developed very successful export-oriented butter and bacon industries by setting up co-ops that collectively established processing facilities for milk and pork. Co-op dairies emerged in 1882 and co-op bacon factories began in 1887. In Sweden, meat-packing associations emerged in 1899, modeled after the Danish ones. Around the turn of the twentieth century, Dutch cooperatives successfully developed industries processing milk, potato starch and sugar (Knibbe, 1993, p. 150). Japan was also successful in promoting rural industries that processed agricultural products, such as silk, through co-ops from the 1920s.

Processed agricultural products require greater product quality control than unprocessed agricultural commodities, particularly for products for the export markets. Typically, countries that import agricultural products, especially processed agricultural products, are richer countries with higher product quality and hygiene standards. The tests and inspections required to meet these standards are beyond the means of small-scale farmers. However, an inability to meet these standards would mean either that the country could not export or that its exports, exhibiting inconsistent quality, would command lower prices than their average qualities would warrant.

Today's rich countries resolved the problem of agricultural product quality management through agricultural marketing cooperatives or state export marketing boards – or indeed a *de facto* merger of the two (as was the case in Denmark between the 1930s and 1950s). The Danish Government imposed quality standards on butter, in association with cooperative butter export associations. The government used a more indirect means for bacon – it encouraged quality improvement through government-endorsed bacon quality competitions (Knibbe, 1993).

Today, underfunded governments in developing countries often struggle to provide adequate services for agricultural product (especially export) quality control, especially for the tests for sanitary and phyto-sanitary requirements. For example, in Zambia, difficulty in meeting the sanitary and phyto-sanitary requirements is a major obstacle to exports, but the Ministry of Agriculture is unable to provide a satisfactory testing service, even in collaboration with the Zambia Export Growers Association (ZEGA).

4. THE ROLE OF INTERMEDIATE INSTITUTIONS

To the extent that a country experiences a sustained process of industrialisation, the development of agricultural technologies becomes more complex and science-based. It thus moves gradually away from the farm to the firm, so to speak. Although on-farm testing, adaptation and evaluation of new technologies are still needed, agricultural machinery and fertilisers are very often manufactured by the machine tools and chemical industries. Thus agrarian change becomes increasingly less dependent on a country's geographical position, climate or natural endowments and increasingly more determined by its manufacturing development, agricultural policies, and the implantation of intermediate institutions. At this stage the two processes of intersectoral learning and technology transfer discussed above become critical. They tend to be facilitated and triggered by intermediate institutions such as agrarian research institutes, technology centres, extension services, quality certification and standards providers.

Historically intermediate institutions have developed different forms characterised by different combinations of the factor inputs policies (and respective functions) described above (section 3). These institutions are called intermediate as they play a critical intermediary role between R&D, education, markets and in-farm agricultural production. They also bridge and transfer knowledge, technical solutions and innovations across different sectors and, thus, facilitate various forms of intersectoral learning (Andreoni, 2013).

Public investment in intermediate institutions and extension services, as well as in vocational schools, exhibitions, fairs and specialised research centres on agro-processing techniques, tend to have an increasingly strong impact over time in the areas or regions where they function. Of course in the short term these institutions and extension services simply provide relief for farmers and farm-cooperatives who cannot afford prohibitively expensive investment in capability building, quality certification, research in agro-processing techniques etc. However, in the medium to long term, the presence of these intermediate institutions helps the accumulation of specific bundles of technological capabilities for agricultural production and technological upgrading, the latter benefitting all producers located in the same area. The agro-technological systems in some regions in the centre-north of Italy, in particular around the Parma agro-centre, are good examples of this phenomenon (Quadrio-Curzio and Antonelli, 1988). Since many of these technological capabilities are not limited to the agricultural sector and in fact develop through a continuous process of intersectoral learning, the concept of *intersectoral commons* is useful here to capture that specific bundle of technological capabilities which are concentrated in certain areas of strong intersectoral interdependence.

The following section provides two in-depth analyses of intermediate institutions in action and the way in which their operation allows the performance of the five critical intermediate functions described above as well as the development of intersectoral commons.

5. INTERMEDIATE INSTITUTIONS IN ACTION: LESSONS FROM LATIN AMERICA

Latin America is undergoing an 'agroecological revolution'. Over the 1990s Chile managed to become the largest exporter of farmed salmon in the world as well as one of the main exporters of fresh and processed fruit and tomatos. Brazil is today among the top three producers and exporters of orange juice, sugar, coffee, soyabeans, beef, pork and chickens as well as having caught up with the traditional big five grain exporters (US, Canada, Australia, Argentina and European Union).

Interestingly, various types of intermediate institutions have been at the centre of the transformative policy package implemented in both countries since the 1970s. In particular, Fundación Chile (FCh) and Embrapa (EM) in Brazil have been increasingly recognised as exemplary institutions which have fostered technological change, diversification and upgrading in agriculture and farming. The following two case studies aim at elucidating the strategic role that intermediate institutions might play in fostering agrarian change. Of course in both cases other public and private actors have also played important roles in the processes of agrarian change.

5.1 THE CASE OF FUNDACION CHILE

Fundación Chile (FCh) is a non-profit private institution created by Decree 1528, issued on August 3, 1976 with a $50 million endowment donated in equal parts by the Government of Chile and the ITT Corporation. In the course of its existence FCh has undergone various phases of transformation with respect to its organisational and sustainability model, partners, sectors and areas of intervention. However it managed to maintain its main vocation as 'a public-private partnership for innovation' as well as its unique 'business orientation'. Specifically, as an intermediate institution FCh focuses on "the identification, adaptation and development of technologies and the diffusion and transfer of these technologies through the creation of innovative companies" (Fundación Chile, 2012).

5.1.1 From the 'daughter of the crisis' to the first 'demonstration projects'

During the presidency of Salvador Allende (1970-73), the socialist government nationalised numerous banks and industries including the Chilean subsidiary of the International Telephone and Telegraph (ITT) Company of the United States. After the Pinochet coup d'état in 1973, the new Minister of Economic Coordination (engineer Raul Sáez) negotiated an agreement with the ITT Company according to which the accorded indemnity had to be reinvested in Chile for the 'joint creation of a Scientific and Technological Research Foundation'.

Behind Saez's proposal there was an explicit intention to transfer some of the technologies owned by ITT's technology laboratory in Spain to Chile (Meissner, 1988). Given the historical conjuncture, FCh was initially perceived as 'the daughter of the crisis'. Indeed, two if its three main areas of focus ('Food technology' and 'Nutrition') were parts of an emergency response to the crisis. The third area, 'Electronics', was seen as a way for capturing and transferring to Chile the technological and organisational capabilities owned by ITT.

With the appointment of a new general director poached from the Spanish ITT technology laboratory FCh began to introduce new business and organisational practices from 1977. Three main departments were created: 'Commercialisation and economic studies', 'Food' and 'Electronics and Telecommunications'. Major efforts were made to identify the critical areas where intervention was needed and to design and test methods of action. FCh increasingly adopted strategies to promote and intensify dialogue with the business sector, raising awareness about the services it offered. In the early years FCh provided free consultation to the private sector, only later adopting innovative marketing strategies (e.g. the organisation of 'work luncheon' at which potential clients and diplomats were invited).

In 1980 five central work areas were selected and Chilean professionals were nominated to head up them (foreign experts were asked to provide advisory services). The selected central work areas were: the *Agro-industrial area*, *Marine Resources*, *Product Development*, *Laboratory* and *Pilot Plant*. For each of them FCh implemented a number of so called 'demonstration projects' aimed at transferring foreign technologies and manufacturing agrarian change, (i.e. the adoption of industrial technologies and science-based innovations by agriculture, aquaculture and farming).

Among the projects selected in 1980 was a feasibility study on the production of vegetable seeds for export. They also did an experimental test on freezing blackberries, strawberries, and vegetables for future export, a study of potato processing and an assessment of green asparagus cultivation. They also studied sanitary improvements of milk handling in industrial dairies with experiments performed on prison populations; technical post-harvest consulting in the fruit industry and quality control of fruit for export (and the utilisation of apple rejects). Research was also done on plant design for the production of dietetic rice-flour; technical assistance was given to canning plants and an aquaculture centre was established in Coquimbo. Finally, technical assistance was given on the refining of fish oil for edible and industrial uses (Fundación Chile, 2012; Bell and Juma, 2007).

Sometimes demonstration projects resulted in the creation of new laboratory (as occurred with the Marine Laboratory and Oyster Growing Station in Tongoy) and this allowed FCh to acquire the official status of 'quality certification entity' for fruits and vegetables exported (in 1985 this license was extended to other products such as meat, seafood, vegetables and housing industries). Others projects, such as the 'Asparagus Cultivation' programme (1979), resulted in massive market successes. After having identified the market opportunity represented by green asparagus (for which there was a high demand in US and Europe) FCh provided technical assistance to farmers to introduce the new variety of asparagus. With this assistance, the area planted and operated grew by 40% of the national acreage dedicated to green asparagus crops. Interestingly, given the great emphasis on agricultural technologies during this initial phase, FCh reoriented the research in electronics and telecommunications toward the design of applications for microprocessors in process control which eventually resulted in processes of intersectoral learning, that is, application of ICT technologies to quality and process control in agro-industries.

5.1.2 The creation of innovative companies: the 'Salmones Antártica SA' model

In 1982 the Chilean economy underwent a profound crisis characterised by a currency collapse and mass bankruptcies related to foreign currency-denominated debts. Coupled with a contraction of international demand this led to a reduction of Chilean exports. In this difficult context FCh decided to introduce a new strategy for technology transfer consisting of direct investment in 'pilot firms'. These firms had to demonstrate the feasibility and applicability of their use of internationally available technologies in the Chilean context. These innovative companies were supposed to attract other Chilean companies in the sector, spreading the innovative technologies across the country. They would also become a new source of finance for FCh after their sale in the market. Often, these companies were jointly created by FCh and existing private companies which had mastered the relevant technologies and had experience in marketing the new products. Among the most innovative companies created by FCh in the first mid of 1980s we found:

- 'Cultivos Marinos Tongoy S.A.', a company applying imported aquaculture techniques and dedicated to the cultivation and export of Japanese oysters (1982);
- 'Caprilac S.A.', an agro-business company dedicated to the production of fine goat's milk cheeses (1983);
- 'Procarne S.A.', a pioneer company operating in the beef industry which successfully introduced the 'vacuum packed format' and the 'deboning at origin' technique, both critically important for adding value and exporting the products;
- 'Berriers La Union S.A.', a company promoting small fruit plantations and the export of fresh raspberries and strawberries;

In 1982 FCh also acquired a company, 'Domsea Farms' (a subsidiary of Campbell Soup) which specialised in aquaculture techniques and was later transformed in the 'Salmones Antártica S.A.' (the first fully integrated company in the Chilean salmon farming industry). At the time the original company was acquired, total national salmon exports were around 300 tons per annum. In 1988, when Salmones Antártica S.A. was sold for $22 million, Chile exported more than 250,000 tons and continued growing over the 1990s approximately 17-fold reaching a world market share of 35% in 2002 (the export value was of $1.2 billion in 2003).

Other companies were sold in the subsequent years, consolidating a model according to which the invested capital was recouped through sale and re-invested in new ventures as soon as innovating technologies were transferred and disseminated through demonstrative companies. Until the end of the 1990s new three main pillars of action of FCh were Agribusiness, Forestry and Marine Resources.

As ‘Salmones Antártica S.A.’ became a model whose story has been widely documented (Meissner, 1988; Huss, 1991; UNCTAD, 2006; Bell and Juma, 2007), we will focus on only a few key elements that determined its success as a company:

- *In-farm learning*: FCh acquired and adopted the salmon ‘cage cultivation’ technology by initial experiments and by hiring national and international consultants as well as training company staff at ranch farms and fish technology centres abroad (Huss, 1991).
- *Inter-sectoral learning*: the fundamental structure of cages was locally produced and made of Chilean wood instead of steel. Additionally a new feed mixture (the highest cost item) was developed in order to employ locally cheaper resources.
- *Institution building* and *technology transfer:* during the 1980s the company built ‘freshwater fish farming centres, seawater grow-out facilities, dry and wet fish feed plants, and processing installations, enabling it to produce smolts, salmon ova, and feed to satisfy its own and third-party needs, as well as fresh and frozen salmon for export’. After its consolidation it also “focused on species diversification, supporting affiliates in operation until their sale, verifying the health of salmon in laboratories, introducing more suitable species of salmon for the XII region and designing model fish culture for Pacific Salmon” (Bell and Juma, 2007:308).

5.1.3 Intersectoral Commons: Fundación Chile and the emergence of agro-technical clusters

Rarely were the successes of the many innovative companies promoted by FCh simply single company successes. Very often they were stories of intersectoral commons and clusters development. For example, in the case of ‘Salmones Antártica S.A.’, the Chilean salmon miracle would have not been possible without the original involvement of the government in salmon research from the 1960s onward and the promotion and joint development of various institutions which constituted and nurtured an intersectoral commons base.

In analysing the public institutions involved we must start with the joint venture between the Chile’s National Fisheries Service (SERNAP) and Japan International Cooperation Agency (JICA) while initially introduced salmon (a non-native fish) to the country. Furthermore, the acquisition of the first facilities for salmon farming by FCh was financed by the regional governmental planning institution of the XI Region (SERPLAC). The first commercial farming venture in Chile able to export to Europe was partly financed by a public agency (CORFO) and was founded by professionals who had worked in government institutions such as IFOP (Fisheries Development Institute). The skills, finance, research and technologies that these institutions developed since the 1960s constituted the intersectoral commons through which in 1987 some 120 firms involved in ocean ranching were based (219 in 1997). Other firms from other industries and sectors such as those manufacturing cages, processing products, producers of refrigerators containers and providers of transport services were forward and backward linked to the salmon industry giving rise to a salmon industry cluster.

One of the main difficulties that firms in the salmon industry faced in the first stages of cluster development was the difficulty of achieving operational scale, international reputation and quality certification. The establishment of a 'Chilean brand' occurred through the constitution of an institution specialised in quality control and certification, (the Salmon Technology Institute or Intesal). This was established in 1994 thanks to the creation of a producer association (Association of Salmon and Trout Producers of Chile) supported by the government. Thus we can see that producers both benefitted from and nurtured the intersectoral commons through which the salmon industry was able to flourish.

The successful emergence of agro-technological clusters is not limited to the case of the salmon industry. FCh was very successful in establishing a 'grape technology platform' which built on genetic engineering technologies. The enormous potential impact of this project was demonstrated by the adoption in other parts of the world of genetically engineered varieties of maize, soybeans, and cotton. At that time "little effort was being expended to make improvements in perennial crop species, such table grapes", a product particularly promising in the Chilean context (Krattiger et al., 2007:8). Starting from these experiments the emergence of a wine cluster in Chile is a well-documented story.

The tomato processing industry is another example of the process described above for the salmon industry and the wine cluster. In the case of the tomato processing industry another public institution (the Production Development Corporation or CORFO) was centrally involved with FCh. CORFO adopted the world's best industrial tomato varieties and transferred the technologies of major established competitors (California, Italy and Portugal) to Chile. The main adaptation consisted in the creation of the 'Malloa model', a network enterprise system allowing the diffusion among SMEs of crop-rotation and cultivation-scheduling techniques.

As discussed above, rotating crops avoids soil degradation while shifting agricultural production permits the exploitation of microclimates and the extension of the production season. Local institutions for collective problems solving were created and joint ventures developed for exporting processed tomato. These institutions were financed by the state starting in 1982 through another state agency (PROCHILE, the Export Promotion Bureau of Chile created in 1975 under the Ministry of Foreign Affairs). Company associations and export committees were financed through a 50/50 scheme with the aim of improving quality to meet international standards and develop new products.

5.1.4 Nurturing the 'Ecosystem' for innovation: mixing selective and horizontal measures

Throughout the late 1980s and 1990s the Chilean economy underwent a drastic transformation: from 1986 to 1996, GDP per capita doubled (from US$3,400 to US$7,360) and exports grew threefold (from US$ 4.2 billion to US$ 15.4 billion). With the increasing dynamism and changing production structures, new institutions such as universities, government agencies (such as CORFO, Innova, Endeavor) and NGOs entered the innovation business that FCh had helped to develop.

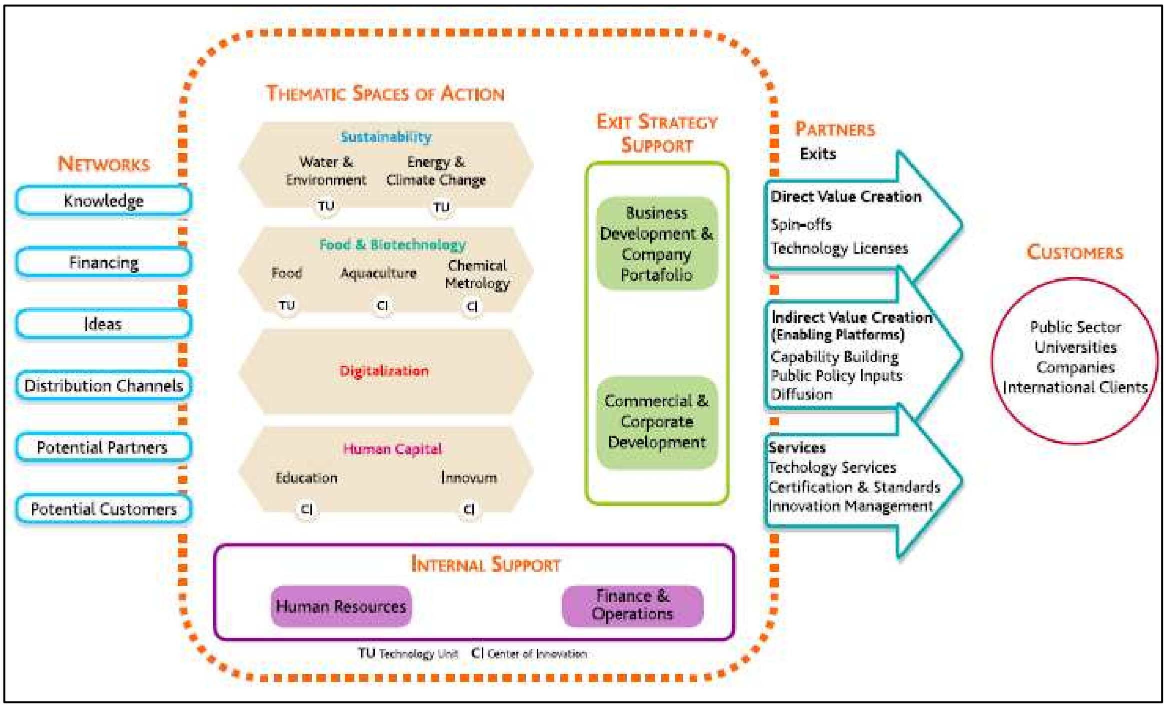
During the 1990s and early 2000s, FCh continued to promote new industries such as the cultivation of abalone and the production of extra virgin olive oil. It also carried on diversifying its portfolio investing in innovative new companies such as 'Oleotop' (2004), the first canola oil producer (replacing fish oil in feed for the salmon industry). However it also initiated the promotion of new more horizontal interventions such as fostering entrepreneurship and human capital in Chile. In 2001, together with the Ministry of Education, FCh created a portal containing 27,000 freely available educational resources and a 'Job Competencies programme' focused on three main areas: certification of job competencies, formation and job market, and management of human resources. Finally, taking stock of its successes in the last few years, FCh has repositioned itself within the 'densifying innovation and incubation ecosystem" (infoDeV, 2011:85) focusing on:

- Creating and promoting "early stage" companies while leaving the "scaling-up phase" to other organisations
- "Making things happen" i.e. operating more as a "do tank" than as a "think tank";
- Nurturing the ecosystem by articulating, coordinating and aligning the interests of key players, both public and private, at the national and international level.
- Filling in the gaps in the agribusiness value-chain and identifying where value is nested
- Development of transversal technologies (see more below)

5.1.5 The current organisational model and the internal operational structure

In 2002 FCh underwent an organisational restructuring that established the basis for the current organisational model. The administration was divided into three main areas: Technology Centres; Business, Investment and Companies Units; and the Corporate Centre. Whereas FCh "used to be organised according to industry sectors (e.g forestry, fruit, salmon, etc.)" it has now been "reorganised in a more transversal, matrix structure according to transversal areas (e.g. sustainability, food and biotech, ICT and human capital)" (InfoDEV, 2011:85). The matrix structure was designed in order to facilitate the collaboration among technology experts and industry specialists coming from different productive sectors (in other words intersectoral learning). The new structure was also meant to facilitate the development of those *transverse technologies* such as information technologies, biotechnologies, engineering services, human resources management and environmental technologies that are essential for upgrading and innovating different industries – i.e. intersectoral commons (see figure 1).

Figure 1: Fundación Chile matrix structure and transversal areas



Source: Fundación Chile, 2012:4.

At the core of this model are the technology centres with their current staff of 350 professionals and more than 200 international consultants. These centres perform three fundamental functions (Fundación Chile, 2012):

i. Identifying opportunities to add value through innovation by exploring market needs.
ii. Obtaining technologies by relying on internal R&D, cooperation and external sources.
iii. Scaling-up and disseminating technologies through the creation of demonstrative companies, the sale and licensing of technologies, supply of technological services, certification and implementation of standards and training.

5.1.6 The governance model: embedded autonomy, competence ownership and sustainability

Since its constitution FCh's governance model was inspired by three main principles:

1. A principle of *embedded autonomy* according to which FCh's priority agenda and strategies maintain a certain degree of independence, although the Chilean government and the private partners are integral parts of its board. The first board of directors was composed by 12 members, six appointed by the government of

Chile (directly by the President) and six by the ITT company. The President of the board and the vice president had to be elected from the government and ITT members respectively, every two years. Moreover, the Board had to elect a Director General (DG) for leading the administration (Meissner, 1988). In 2005, another private company BHP Billiton Escondida Mining was incorporated as co-founding member and entered the board. Furthermore, in order to facilitate inter-agencies coordination, top authorities of Chilean national development agencies CORFO and CONICYT were also included in FCh's Board of Directors as government members.

2. A principle of *competence ownership* was applied according to which Chilean nationals had to be increasingly involved in the management of FCh, at all levels. For this reason, from the very beginning, ITT was asked to organise in-house training programmes to prepare qualified candidates for management positions. A formal technical assistance contract with ITT was also agreed. ITT was reimbursed for direct costs incurred and guaranteed intellectual property protection for innovations resulting from the application of its technologies. Technical competences were given higher priority and linked to higher management positions. Thus the first FCh staff (the so called Founding Party) were constituted by a former food industry R&D executive, a food technologist, a nutritionist, a chemical engineer and an ITT telecommunications specialist (Meissner, 1988).

3. A principle of *sustainability*, according to which FCh had to obtain balanced financial flows and achieve full-financial sustainability over time. This principle was enforced particularly strictly during the 1980s and increasingly pushed a strong shift towards more practical projects that could translate into commercial ventures and returns as well as greater concern for the market and clients. In thirty years, the application of this principle has led FCh to move from revenue of $2.5 million and 0% self-financing to revenue of $31.5 million (including activities resulting from the merger with Intec) and 88% self-financing (Fundación Chile 2012). In order to achieve these results, FCh adopted a financial monitoring system called 'Annual Evaluation of Results of the Operations Program (AEROP) (Meissner, 1988).

5.2 THE CASE OF EMBRAPA IN BRAZIL

Established in 1972 via Law 581 as a public corporation under the Ministry of Agriculture, Livestock, and Food Supply (MAPA), Embrapa (*Empresa Brasileira de Pesquisa Agropecuária*) is the national agricultural research agency of Brazil. Brazil is a country with one of most well-developed and well-funded research systems in the developing world (in terms of public investment in agricultural research it is below only China and India). The Agricultural Research system involves federal and state governments as well as an enormous number of agricultural universities (around 80). There are also a very large number of agricultural research centres, (some of them have been in existence since the early 19th century). This makes the current Brazilian agricultural research system extremely complex and characterised by overlapping networks (17 state research networks in 2011). Embrapa stands as the main player within this complex system. With its 47 research centres throughout the country hosting 9.284 employees and an annual budget of over US$ 1 billion in 2011, it is the largest R&D agency in Latin America by staff and budget. The research centres are organised along three main axes of specialisation: commodities, resources and themes. In 2011 Embrapa counted 15 National 'Thematic' Centres, 16 National 'Commodity' Centres and 16 Regional 'Resource' Centres. The full list is provided in the table (Rada and Buccola, 2012: 364).

5.2.2 Embrapa's Establishment and Development over forty years

In the 1960s the Brazilian military government started a profound reorganisation of the Brazilian agricultural research system. It aimed to increase national agricultural research capacities, trigger farm modernisation and enhance food production (partially as a response to the food crisis generated by urbanisation and partially to boost exports and earn additional foreign revenue). One of the main Brazilian public agencies, the Department of Agricultural Research and Experiment (DPEA), renamed DNPEA (National Agricultural Research and Experiment Department) in 1971, was charged with improving the technological capabilities of Brazilian agricultural research institutes. They did this by training their researchers to the postgraduate level and conducting research projects on commodities and areas considered priorities for national development.

Embrapa was founded in 1972 as a response to the main weaknesses of DNPEA. These included "researchers' lack of awareness of the basic needs of agriculture and the lack of intradepartmental and external interaction among researchers, extension workers, and farmers (which had led to instances of unproductive duplication of research efforts)". Other weaknesses involved "the lack of incentives for researchers (particularly indicated by low salaries), the low level of postgraduate training (12 percent the scientific staff at the time), and finally the insufficient, and often irregular financial resources available" (Beintema et al., 2001:16). Embrapa took over DNPEA's extensive network of research institutes covering the main agricultural commodities and regions, experiment stations, and existing projects. Agricultural extension services were outside Embrapa's area of intervention and were assigned to another agency, Embrater, which operated until 1991.

During its first decade, Embrapa created its network of national commodity centres and regional centres that focused on major cropping and animal production systems as well as on eco-regional and national themes. It also increased its internal capabilities by signing partnerships with US universities such as Purdue and Wisconsin, which allowed Embrapa's staff to receive postgraduate training. By implementing a 'Concentrated Research Model' Embrapa also operated as a 'capacity building coordinator' by stimulating the creation of state corporations for agricultural research. Total government investment in the first twelve years of Embrapa's life was around six billion dollars in 2008 value (Alves, 2010).

By the mid-1980s the severe financial crisis dramatically reduced Embrapa's funding (its performance was criticised as the immediate impact of agricultural research on the Brazilian economy were hard to pinpoint). As a response to the crisis Embrapa decentralised its operational model. The new 'Circular Programming Model' promoted inclusive strategies for the definition of research programmes and facilitated greater interaction with farmers and federal states to better capture the local needs of Embrapa's clients and end users.

Furthermore greater emphasis was now given to research with short-term returns, multidisciplinary in scope and intersectoral relevance, while more efforts were made to disseminate existing results (Silva and Flores, 1993). Also, at the level of administration, research centres were accorded more freedom on matters of budget and resource allocation (although major policies continued to be set centrally). The reorganisation process was concluded in 1993 when a five years strategic plan (called a Director Plan) was started to be implemented. The establishment of the Embrapa Planning System (SEP) introduced for the first time a systems approach to R&D planning for the first time. This allowed a redefinition and reintegration of the centre's mission, objectives, programmes, human resources, infrastructural needs and priorities.

Agricultural research started being ever-more cross-pollinated by research in advanced manufacturing. A good example of this is the satellite monitoring services for the acquisition and processing of remote sensor images and field data. The Satellite Monitoring Centre was created in 1989 in an area of 20,000 sqm in Campinas (Sao Paulo state) assigned by the Brazilian Army to Embrapa for the development of a special unit focused on territorial management systems and electronic networks for modern agriculture.

Throughout the 1990s "Embrapa was involved in a wide range of activities related to agricultural research and technology including plant breeding, pest management, food safety, satellite monitoring, sustainable agricultural development, and hunger relief. Soybean breeding and pest management activities are headquartered at the Embrapa facility in Londrina in the state of Paraná, but crop research activities are carried out at locations around the country to develop crops and varieties that are suited for local conditions" (Matthey et al. 2004: 10).

The trend started in the 1990s continued during the next decade, in particular in 2005-2006, when Embrapa made a massive efforts to improve and renovate its infrastructure. A R$ 21 million investment was designated to the labs. However, if we include the full range of funding provided for facilities, equipment, tractors and vehicles we reach R$ 90 million. Included among these investments, at the interface between agriculture, biotechnologies and advanced manufacturing were:

- Facilities for quality improvement in the meat production chain.
- An aquaculture lab prioritising water quality control, fish feeding and health.
- A new Enology Lab to boost wine production in the Northeastern Semi-Arid Region.
- The construction of a worldwide unique National Agribusiness Nanotechnology Lab focused on the development of sensors and biosensors for food quality control, certification and traceability. The Lab was also dedicated to the synthesis of new materials such as polymers and nanostructured materials or thin films and surface to manufacture smart packages.
- Six new walk-in freezers to increase the storage and preservation capacity of the Embrapa Germplasm Bank (from 120 to 240 thousand seeds).

According to information provided by the Brazilian government, Embrapa has generated and recommended more than nine thousand technologies for Brazilian farmers since its inception in 1973. This includes developments in tropical agriculture that have developed an extraordinary network of intermediate institutions, research centres, labs and other facilities. In 2007 it was estimated that Embrapa's lab infrastructures encompass 215,500 m^2, 33,000 m^2 of canvas covered facilities and 35,000 sqm of greenhouses (Embrapa, 2007; see also Embrapa 2012). This demonstrates the massive investment that the Brazilian government made in order to provide an appropriate scale for the intermediate institutions.

5.2.3 Embrapa and the Cerrado miracle

Probably the most remarkable achievement of Embrapa has been the reclaiming of the *cerrado* (the Brazilian savannah) for modern agriculture. Before Embrapa achieved this, "nobody thought these soils were even going to be productive" declared by Norman Borlaug, the famous Green Revolution plant scientist.

The *cerrado* constitutes a major portion of the almost 400m hectares of arable land in Brazil (only 50m of which is in use according to the FAO's estimates). The *cerrado* is concentrated in the centre of Brazil, around its capital. When Brasilia was created in 1961 the federal government invested enormous resources in infrastructure to link the capital to the rest of the country. They also developed programmes to encourage the migration of farmers from the South. Coming from more agriculturally advanced regions migrants possessed technological capabilities which were critical for the application of the innovations developed by research institutes located in the Federal District of Brasilia, such as Embrapa Cerrado, Embrapa Vegetables and Embrapa Genetic Resources and Biotechnolgoy.

Embrapa was the key agency for the success of agriculture in the *cerrado* (Alves, 2010:70). Embrapa's technological efforts were also reinforced by government investment which established new universities and postgraduate courses in all states of the *Cerrado* region. The alignment of policies and programmes at the inter-institutional level eventually generated critical competences in *cerrado* agriculture which resulted in the sedimentation of intersectoral commons in the area and intense processes of intersectoral learning.

From an agronomic point of view, Embrapa's strategy to make the *cerrado* land productive was fourfold. Firstly during the 1990s and increasingly in the early and mid-2000s, the acidity of the soil was reduced by pouring industrial quantities of pulverised limestone or chalk into the *cerrano* soil. At the same time Embrapa was working on a bacterium that encouraged nitrogen-fixing in legumes which reduced the need for fertilisers in the cerrado's nutrient-poor soil (Hosono and Hongo 2012).

Secondly Embrapa imported a grass called *brachiaria* from Africa. This was a new variety of grass created through crossbreeding. The higher productivity of this new variety (20-25 tonnes of grass feed per hectare) increased the amount of forage produced and thus allowed farmers to increase beef production.

Thirdly, soyabeans, a temperate-climate crop, were transformed into a tropical crop by crossbreeding and by introducing genetically modified soya seeds. The new varieties of soya require a shorter biological production cycle, allowing farmers to grow two crops a year. This manufactured transformation of the soya production process had profound impact in farmers' crop-growing techniques.

The fourth and last technological innovation introduced by Embrapa concerns the agricultural work of soil preparation and the agriculture and livestock integration. The new 'no-till agriculture' technique developed means that the soil does not need to be ploughed nor the crop harvested at ground level (the outmoded traditional manner). By harvesting the crop at a higher level the part of the crop that remains in the ground constitutes a natural input for agricultural reproduction in terms of nutrients for the next year. The new crop will be directly planted into the mat of organic material left from the previous 'not-till' harvesting (Hosono and Hongo 2012).

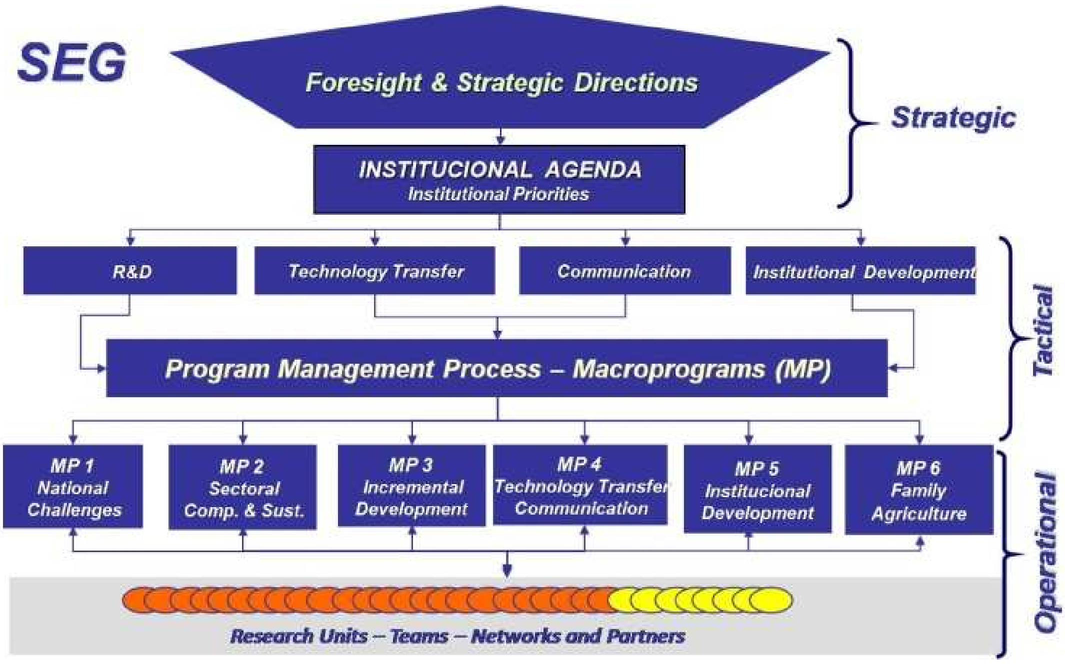
Although practiced since the first agricultural revolution Embrapa rediscovered and promoted a rotation scheme according to which fields are used alternately for crops, livestock and then tree-planting. Although possible through the use of fertilisers, this rotation scheme remains a cost-effective way for rescuing pasture lands. In sum, as a result of Embrapa's innovation, in 2010 the "unproductive" cerrado accounted for 70% of Brazil's farm output

5.2.4 Embrapa current decentralised model, management system and governance

Embrapa's applied research model is a decentralised one (figure 2). Regional-resource (RR) centres focus on a state or region, biome or climate rather than on a national-scope product, the latter being covered by National Commodity (NC) centres. Together they account for roughly 4/5 of the total Embrapa budget and staff. The Thematic research centres provide support to RR and NC centres by concentrating on basic research problems spanning the whole the country such as soil conservation, satellite imagery, genetics and biotechnology (Rada and Buccola, 2012).

Embrapa's management model underwent four major transformations. The last one was implemented between 2001 and 2003 and involved the introduction of the *Embrapa Management System* (SEG) which explicitly aimed at aligning the R&D process with the organization's efforts in communication, technology transfer and institutional development. As the following table illustrates, the SEG system is structured so that all Embrapa's projects are aligned in the design, implementation and assessment phases and are organised within six Macroprograms, covering R&D, communication, technology transfer and institutional development. The final aim of the SEG system is to optimise the use of inputs, guaranteeing biological reproduction and the preservation of agro-biodiversity with adequate soil and water use and management.

Figure 2: Embrapa's decentralised model



Source: Embrapa website

Embrapa's governance model exhibits the characteristics of the embedded autonomy model we also discussed in the case of Fundacion Chile. The board of trustees which governs Embrapa is composed of six members: two representatives each from the government and the private sector, the president of Embrapa, and the vice-minister of MAPA. The implementation of the board's strategies is left to an executive board of directors, consisting of a director-president and three executive directors, who are appointed following the recommendations of MAPA. Finally, the leaders of the research centres are hired through an open public selection process. Stakeholders are members of "External Advisory Boards", for all 47 EMBRAPA's Research Centres.

6. CONCLUDING REMARKS

There is a lot to learn from history about improving agricultural policy in today's developing and transition economies. The paper has shown that here has been enormous variety in the institutional forms that have successfully delivered critical needs of the agricultural sector. These institutions vary enormously across time and space. There were successes and failures with all forms of delivery in all sorts of countries – public provision, private provision, private delivery subsidized by the state, public-private partnerships, cooperatives, state-cooperative partnerships and so on. All these examples suggest the importance of a pragmatic approach, not bound by pro-state or pro-private-sector ideologies and the need for more policy imagination.

Indeed our analysis shows that the willingness to experiment with new policies and institutions and the willingness to learn from and improve upon other countries' successes were important in all agricultural success stories, ranging from Germany in the nineteenth century to Chile and Brazil in the last few decades.

The possibility of influencing and directing the process of agrarian change through the creation of intermediate institutions has been analysed through two case studies, respectively Fundación Chile and Embrapa. The two case studies elucidated the different forms, functions and functioning of intermediate institutions and provided evidence of the fact that governments can play an 'entrepreneurial' role in fostering agrarian change. We also showed that in order to make policy making more effective we need to open up the black box of agricultural production and perform a detailed techno-institutional analysis of various potential types of intermediate institutions.

What was traditionally thought being 'a decreasing returns' sector, thanks to these intermediate institutes, agriculture has become a new frontier for technological innovation and value capture.

References

Alves, E. (2010) *Embrapa: a success story of institutional innovation*, Brasilian Agricultural Research Corporation, Brasilia DF.

Andreoni, A. (2011) 'Manufacturing Agrarian Change: Agricultural production, intersectoral learning and technological capabilities', DRUID Working paper 11-13.

Andreoni, A. (2013) 'Structural Learning: Embedding discoveries and the dynamics of production', *Structural Change and Economic Dynamics*, http://dx.doi.org/10.1016/j.strueco.2013.09.003

Beintema, N.M., A.F.D. Ávila and P.G. Pardey (2001) *Agricultural R&D in Brazil: Policy, investments and institutional profile*, IFPRI, Embrapa and Fontagro, Ago, Washington, D.C.

Bell, B.W. and Juma, C. (2007) 'Technology prospecting: lessons from the early history of the Chile Foundation', International Journal of Technology and Globalisation, vol. 3, n. 2/3, 296 – 314.

Byerlee, D. and Fischer, K. (2002) 'Accessing Modern Science: Policy and Institutional Options for Agricultural Biotechnology in Developing Countries', *World Development*, 30(6), 931-948.

Chang, H-J. (2002) *Kicking Away the Ladder – Development Strategy in Historical Perspective*, London: Anthem Press.

Chang, H.-J. (2009) 'Rethinking public policy in agriculture: lessons from history, distant and recent', *Journal of Peasant Studies,* 36(3), 477-515.

Chang, H.-J. (2009b) 'Under-explored Treasure Troves of Development Lessons – Lessons from the Histories of small Rich European Countries', in *Doing Good or Doing Better – Development Policies in a Globalising World,* Amsterdam: Amsterdam University Press.

Chang, H-J. (2011), ed., *Public Policy and Agricultural Development*, Routledge ISS Studies in Rural Livelihoods.

Colman, G. (1965) 'Government and Agriculture in New York State', *Agricultural History*, 39, 1.

Embrapa (2007) *Tropical Agriculture: Brazil Building the Future*, Embrapa.

Embrapa (2012) *Brazilian Agriculture. Development and Challenges,* Embrapa.

FAO (1966) *Agricultural Development in Modern Japan – The Significance of the Japanese Experience*, Rome: FAO.

FAO, UNIDO and IFAD (2009) *Agri-industries for Development*, edited by C. da Silva et. al., UN Publisher.

Krattiger, A. RT Mahoney, L Nelsen, et al., eds., *Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices*, MIHR: Oxford, U.K., and PIPRA: Davis, U.S.A.

Fundacion Chile (2012) 'Fundación Chile over time'.

Hayami, Y. and Ruttan, V. (1973) 'Technology Transfer and Agricultural Development', *Technology and Culture*, 14(2),119-151.

Henriksen, I. (1992) 'The Transformation of Danish Agriculture, 1870-1914, discussion paper, Institute of Economics', in K. Persson (ed.), *The Economic Development of Denmark and Norway since 1870*, Edward Elgar, Aldershot.

Hosono, A. and Hongo, Y. (2012) *Cerrado Agriculture*. *A model of Sustainable and Inclusive Development*, Conference volume, JICA and Rio+20.

InfoDEV (2011) *Growing food, products and business: applying business incubation to agribusiness SMEs'*, Washington DC: World Bank.

Ingersent, K. and Rayner, A. (1999) *Agricultural Policy in Western Europe and the United States*, Edward Elgar, Cheltenham.

Kay, C. (2009) 'Development strategies and rural development: exploring synergies, eradicating poverty', *Journal of Peasant Studies,* 36(1), 103 – 137.

Knibbe, M. (1993) *Agriculture in the Netherlands, 1851-1950: Production and Institutional Change*, NEHA, Amsterdam.

Koning, N. (2007) 'What Can Be Learned From the History of Developed Countries?', In N. Koning & P. Pinstrup-Andersen (eds.), *Agricultural Trade Liberalization and the Least Developed Countries*, Springer, New York.

Matthey, H., Fabiosa, J. and Fuller F. (2004) 'Brazil: The Future of Modern Agriculture', MATRIC Briefing Paper, May.

Meissner, F. (1988) *Technology Transfer in the Developing World: The Case of the Chile Foundation*, New York: Praeger.

Pardey, P., Alston, J. and Ruttan, V. (2010) 'The economics of innovation and technical change in agriculture', in B.H. Hall and N. Rosenberg eds. *Handbook of the Economic of Innovation*, vol. 2, pp. 939-984.

Quadrio-Curzio, A. and Antonelli, G. (1988) *The Agro-technological System towards 2000*, North Holland: Elsevier.

Rada, N. and Buccola, S. (2012) 'Agricultural Policy and Productivity: Evidence from Brazilian census', *Agricultural Economics*, 43 (4), 355-367.

Rosenberg, N. (1979) 'Technological Interdependence in the American Economy', *Technology and Culture*, 20, 1, 25 – 50.

Tracy, M. (1989) *Government and Agriculture in Western Europe, 1880-1988*, 3rd Edition, Harvester Wheatsheaf, New York.

van Zanden, J. (1991) 'The First Green Revolution: The Growth of Production and Productivity in European Agriculture, 1870-1914', *Economic History Review*, 44(2).

World Bank (2008) *World development report 2008: Agriculture for Development*. New York, NY: Oxford University Press.