207

DISCUSSION PAPER

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207

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CONTENTS

ABSTRACT

Economic development theories and their learning frameworks differently address farms and firms. This article argues that the traditional double-standard of the primacy of manufacturing rests on a debatable stages model that under-recognizes learning and innovation in agriculture and its crossover supplier segments with manufacturing. The sections analyze manufacturing bias; demand's effects; and differences in the technological process and links between agriculture and manufacturing. It then analyzes the learning implications of two theories – unlimited labor and induced innovation – on economic development. The article concludes with the implications of the distinctive learning dynamics within and between farms and firms. An evolutionary approach has potential for understanding both manufacturing as well as agriculture, but should be more carefully extended to consider the inter-linkages between the two to extract the maximum developmental benefit. It is clear that models that connect learning and innovation to growth require closer attention and have important developmental consequences through policy design.

Keywords: agriculture, industry, economic development, learning and innovation.

1 INTRODUCTION

This article analyzes the technological dynamics of modern production and the coexistence of "modern" and "backward" sectors, the roots of such theorizing and the implications for more dynamic frameworks of learning in economic development. The arguments rest here on how learning is represented, what assumptions are made of the relationship (dynamic or not) between agriculture and manufacturing, and the ways in which science, technology and productivity growth are claimed for manufacturing *versus* agriculture. These issues have become ever more crucial in the era of climate change, the pressures of industrial growth, food scarcity, employment opportunities, and fluctuations in commodities trade. Furthermore, land has become ever more scarce which sets limits to more sustainable and efficient farming and requires more attention to the political economy of learning.

The study is motivated by the following questions: How can we understand the role of agriculture in an industrial transformation process of interdependence? In what ways are institutional models for technical change and learning in agriculture diverse? Under what conditions do models of agriculture in economic development hold potential for regional growth? Thus, how much reliance should be placed on manufacturing as an engine of growth? Furthermore, if technological learning is to offer learning and productivity gains, in what way do learning dynamics connect agriculture and manufacturing?

In most economic development models, agriculture is seen as a more passive supplier to manufacturing. We argue that this arises from a debatable economic two and three sectors stages model of growth and development. Specifically, the gap between agriculture and manufacturing lies in the skew of how we read learning in 2-sector models and their "fit" in a history read as economic development stages. In our view, a small part of all technological development and new knowledge in agriculture come with the acquisition of inputs. Moreover agricultural producers are not simply receptors of technology. Agri-industrial innovation depends on an institutional framework that stimulates public knowledge and technological opportunities in the entire economy. In addition, the producers' absorptive capacity of accumulating knowledge determined on-site also drives innovation in the agricultural sector.

The implications for the differences between farms and firms is critical to countries such as Ethiopia where agriculture contributes heavily to both Gross Domestic Product (GDP) and to employment, but whose linkages to manufacturing are weak at best.

It also has implications for nations such as India and Brazil, which have variable manufacturing capabilities. Yet both have struggled in terms of GDP and job growth, and have struggled to establish robust learning systems for agriculture. Both countries had directed strategies for their Green Revolution, yet weak institutional crossover to manufacturing. Even in developed nations such as the United States and Europe, agriculture is subsidized because it is strategic for economic planning and cultural-historical reasons, rather than directed action towards technological dynamism. Similarly, many countries emphasize manufacturing over other sectors ("Make in India" most recently, and China's immense drive to labor-intensive and higher-value addition manufacturing). Yet both struggle with agricultural concerns and uncertain employment and slowed-migration returns to manufacturing investment. The land-use intensity of manufacturing and agriculture is also different, pointing to questions of how learning can boost these gains.

We proceed in the following manner. In order to analyze the differences between farms and firms, Section 2 characterizes the bias toward manufacturing. Section 3 lays out how demand and innovation are differently structured in agricultural learning. Section 4 takes learning differences to analyze the institutional ties between agriculture and manufacturing in the growth process and development. Section 5 presents a critical review on two- and three-sector models and revisits two influential models: the surplus labor (Lewis, 1954) and the induced innovation (Hayami and Ruttan, 1985), to elaborate on why a more classical political economy in these can benefit from a learning framework. Finally Section 6 concludes with implications for economic development and some new questions.

2 THE BIAS TOWARD MANUFACTURING

If manufacturing is to play a pivotal role in economic development, what assumptions underlie this? There has been an abiding perception that to promote economic development it was important to boost agriculture accumulating previous capital, and then uses this to fuel industry. In an advanced stage the economy would incorporate a greater services sector. Analyzing data from agriculture, industry and services, in terms of value added as a percentage of GDP, we can summarize that agriculture has shown a decreasing GDP share with negative growth rates over the past few decades. On the opposite side, services have presented an increasing share, and positive growth rates for most countries. In the middle, we can observe manufacturing, where there are some countries, such as China, India and Ethiopia, which have increased their share. However, other countries, such as Argentina, Brazil, Chile, France, Germany and the United States, have shown decreasing percentages. Regarding income stratification in high-income countries, the observed trend is the reduction in the industrial share (see table 1).

TABLE 1
Growth rate of agriculture, industry and services value added by selected countries and income classification (1965-2012)

Indicators	Countries and income stratus	Years			Geometric growth rate		
		1965	1990	2012	1965-1990	1990-2012	1965-2012
Agriculture value added (% of GDP)	Argentina	12.9	8.1	6.9	-1.8	-0.7	-1.3
	Brazil	18.7	8.1	5.3	-3.3	-1.9	-2.6
	Chile	8.7	8.7	3.4	0.0	-4.2	-2.0
	China	37.9	27.1	10.1	-1.3	-4.4	-2.8
	India	40.9	29.0	17.5	-1.4	-2.3	-1.8
	Ethiopia	58.1[a]	52.0	48.0	-	-0.4	-0.6[a]
	France	8.9	3.5	1.9	-3.7	-2.9	-3.3
	Germany	-	1.2[b]	0.9	-	-1.5[b]	-
	United States	-	1.4[d]	1.3	-	-0.3[d]	-
	Low income	38.2[a]	37.5	27.6	-	-1.4	-1.1[a]
	Middle income	31.0	19.6	9.9	-1.8	-3.0	-2.4
	High income	-	2.1[d]	1.5	-	-2.4[d]	-
	World	-	6.4[c]	3.1	-	-4.2[c]	-
Industry value added (% of GDP)	Argentina	48.4	36.0	29.6	-1.2	-0.9	-1.0
	Brazil	33.6	38.7	26.0	0.6	-1.8	-0.5
	Chile	39.9	41.5	36.3	0.2	-0.6	-0.2
	China	35.1	41.3	45.3	0.7	0.4	0.5
	India	20.4	26.5	26.2	1.0	0.0	0.5
	Ethiopia	9.3[a]	9.8	10.3	-	0.2	0.3[a]
	France	34.4	26.9	20.0	-1.0	-1.4	-1.2
	Germany	-	36.8[b]	30.7	-	-0.9[b]	-
	United States	-	24.0[d]	21.0	-	-0.9[d]	-
	Low income	18.5[a]	19.2	23.3	-	0.9	0.7[a]
	Middle income	29.3	36.2	35.9	0.8	0.0	0.4
	High income	-	28.5[d]	24.8	-	-0.9[d]	-
	World	-	32.8[c]	26.8	-	-1.2[c]	-
Services etc. value added (% of GDP)	Argentina	38.7	55.9	63.5	1.5	0.6	1.1
	Brazil	47.7	53.2	68.7	0.4	1.2	0.8
	Chile	51.4	49.8	60.3	-0.1	0.9	0.3
	China	27.0	31.5	44.6	0.6	1.6	1.1
	India	38.7	44.5	56.3	0.6	1.1	0.8
	Ethiopia	32.6[a]	38.2	41.8	-	0.4	0.8[a]
	France	56.7	69.6	78.2	0.8	0.5	0.7
	Germany	-	62.1[b]	68.4	-	0.5[b]	-
	United States	-	74.6[d]	77.7	-	0.3[d]	-
	Low income	41.7	43.6	49.1	0.2	0.5	0.3
	Middle income	39.3	44.3	54.1	0.5	0.9	0.7
	High income	-	69.4[d]	73.7	-	0.4[d]	-
	World	-	60.8[c]	70.2	-	0.8[c]	-

Source: World Bank (2014).
Notes: a. 1981; b. 1991; c. 1995; and d. 1997.

In a dynamic view however, it is important to understand the interaction between these sectors and consider the weight of learning and innovation to raise productivity. If economies were indeed getting less or more industrial, it would be necessary to distinguish the contributions of manufacturing and agriculture to the phenomenon and of differential effects of learning in each. Neo-Schumpeterian approaches to learning have shown how important technical change is to growth and institutional reform (Nelson and Winter, 1982; Dosi, 1984; Sahal, 1985; Freeman and Perez, 1988; Cohen and Levinthal, 1989; Lundvall, 1985; 1992; Chiaromonte and Dosi, 1992; Nelson, 1993; Edquist and Hommen, 1999). The core of such technical change is that entrepreneurs and other agents search for innovations to build new products, creating monopolistic market and increasing profits, and create new knowledge or techniques thereby expanding efficiency and saving productive factors. In business firms, this process evolves in a stochastic fashion, creating windfall profits to those entrepreneurs and financiers who bear the risk, and thus create a theoretical dynamic tying what occurs within the firm through a search and learning process, into the more macro-level business cycle with repercussions on the entire economy.

The bias toward manufacturing has many sources and we cannot address them all here. However, two elements of how manufacturing is imagined are worth emphasizing: first, it requires attention to recognizable units of production termed business firms which are conceptualized as standardized units involved in the search and learning process; second, these firms are perceived as belonging to a productive institutional environment of chains, networks, and other linkages, in which productive outputs are diffused. According to Dosi (1984), the industrial chain illuminates a system of interdependence based on input-output and technological relations. Another way of describing this is that any adoption of new technology is based on previous accumulated knowledge as a mechanism of experimentation that, once successful, influences the diffusion of this new technology and which in turn can crucially depend on user-producer linkages (Lundvall, 1992).

Although there has increasingly been questioning of whether the business firm as seen in advanced industrialized economies is as relevant as the development dynamics of many developing contexts, and also, whether the search and learning process is appropriately characterized to account for scarcity-induced, frugal and other non-conventional innovations whose insertion in global value/supply chains may be less than evident (Srinivas and Sutz, 2008; Arocena and Sutz, 2010; Kaplinsky, 2011), by and large the standard model has remained the business firm rooted in manufacturing history and one with recognizable characteristics such as

"R&D", managers, workers and with lines of credit. Furthermore, the exclusion of these forms of learning and innovation is closely tied with structural change and policy design and recognition.

In the more dominant manufacturing as well as agriculture literature focused on industry clusters and global value chains, there have been several similar attempts to analyze the learning and competition process (Humphrey and Schmitz, 2002; Giuliani *et al*., 2005; Ponte and Gibbon, 2005; Morrison *et al.*, 2008). These studies highlight the institutional mechanisms that are increasingly driving new types of learning and regulation within the chains. For instance, not only does it matter where a firm becomes inserted in such a chain, but also the chain itself and the types of learning induced, might be "buyer-driven" or of other types. The manufacturing, retail, services, and agri-business value chains have all been thus studied.

Sector-wise studies in late industrializing economies in particular resonate that substantial learning has occurred from electronics to semiconductors, and biotechnologies (Griliches, 1957; Lall, 1982; 1993; Amsden, 1989; 2001; Katz, 1984; Kim, 1997; Nelson, 1993; Lundvall, 1992; Foster and Rosenzweig, 1995; World Bank, 1996; Cimoli and Katz, 2002; Iizuka and Katz, 2010; Niosi and Reid, 2007). What the late industrial literature has also shown is that particular types of learning become crucial in certain phases of global market competition; learning to respond to domestic and export demands is a particular skill and political tension. Certain types of learning are prioritized by firms and policy-makers (e.g. export-directed consumer electronics, vaccines) and certain institutional arrangements legitimized (e.g. joint ventures, contract research, process patents) (see especially Lall, 1983; Kim, 1997; Srinivas, 2012). In turn, although the learning embedded within such manufacturing chains is highly dependent on fragmentation of production processes, the extent of such fragmentation can be shaped to some degree by policy.

Although it is the manufacturing literature that has most been the focus of learning studies, we see learning's continued importance in sectors that straddle manufacturing and agriculture, and which can have important developmental attributes because of the geographic cross-over from rural and urban areas alike, because of under-specification in sectors affecting basic needs agendas from electrification, healthcare, waste management, to food production and energy services (Srinivas, 2014). One of the enduring gaps is of course how these types of learning in manufacturing sectors and in agriculture influence the developmental agenda of assuring basic needs, boosting incomes, offering work opportunities, and creating dynamic firms.

Therefore, not all sectors offer the same learning or productivity spillovers, and strategies matter. In the exploitation of natural resource sectors, too, some may offer fewer spillovers and little technological upgrading (e.g. mining enclaves), but there can be others with more (Perez, 2010). Thus, less developed countries may benefit from windows of global opportunity they are offered (Perez and Soete, 1988), as we have seen in how Brazil, India, and China have differentially positioned and benefited from biotechnologies and nanotechnologies (Niosi and Reid, 2007).

Despite this bias toward manufacturing, there are clues in the study of manufacturing-based learning studies that can provide a way into agriculture. Imitation for instance has played a vital role in manufacturing, because it refers to the dynamic to assimilate existed knowledge (Kim, 1997). On the other hand, problem-solving skills denote the ability to create new knowledge or innovation. Lead firms in Korea incorporated learning operational skills and elementary innovation before creating their own capacity to solve problems. They were able to learn, assimilate and adopt foreign technologies before starting an internal and virtuous cycle of innovation. The technological capabilities are both knowledge as well as technical and managerial skills (Dosi, 1988; Bell and Pavitt, 1993). Internal and external boundaries form an important concept therefore to characterize how a firm can build its technological capability by investing in creating new knowledge or in expanding its ability through absorptive capacity to absorb external knowledge (Cohen and Levinthal, 1989).

Latecomer firms then develop absorptive capacity over time toward their own innovation outcomes and in-house R&D capabilities. Not just firms, but as national outcome, Korea successfully transformed from an importer to a technology exporter country (Kim, 1997). Firms evolved their absorptive capacity and many foreign technology-licensing contracts involved know-how (tacit knowledge), which has been superior mechanism to consolidate absorptive capacity than the licensing of patent rights (codified knowledge) to advanced technologies (Chung and Lee, 2015).

3 DEMAND'S EFFECTS UPON LEARNING AND INNOVATION IN AGRICULTURE

Mowery and Rosenberg (1979) argue that an innovation can be introduced because the demand for a product has increased (in other words, the demand curve has shifted outward) or because technological improvements were created (other sources of cost reduction that implies in a downward shift in the supply curve). While the manufacturing studies proved invaluable to emphasizing the importance of learning and the crucial role of absorptive capacity, a focus on manufacturing assumed and obscured its wider institutional environment. After all, the demand for manufacturing in many of these studies was generated primarily if not exclusively through export demand (Srinivas, 2014; Dosi, 1988).

Agriculture can therefore benefit from insights on how both domestic demand and export demand played important roles in manufacturing. In agriculture however, it is harder to separate the contribution of demand and supply sides. Although it seems that the demand side drives technological improvements by understanding that agriculture is heavily influenced by exports, learning and the innovations it generates can rest on both demand-pull and technology-push. The diffusion process is important to the supplier segment in order to increase sales and expand profits. When adapting the new technology into specific regional productive conditions, the interdependency between the unit of production and the supplier industry is defined by the exchange of information (Vieira Filho, 2012).

Brazilian agriculture provides a good example of this phenomenon. Since the early 1970s, Brazil has experienced enormous agricultural productivity growth associated with a clustering of innovations. The agricultural liming technique turned the acidic soil of the Cerrado[1] into arable land. The expansion of Brazilian agricultural frontier demanded the "tropicalization" of the soybean crop whose seed varieties were more tolerant to tropical climates (drier and warmer at lower latitudes). At the same time, the inoculation of bacteria in soybean seeds that capture soil nitrogen allowed more production with less fertilizer use, contributing to raise yields per hectare. As a result, the marginal price of land was kept down and, consequently, mechanization was introduced on a large scale, facilitated by geographic characteristics, flat lands and pattern suitable rainfall. During the 1960s, soybean production attained the same importance of wheat production in southern Brazil. In parallel, production of pork and poultry created additional demand for soybean meal as an important source of animal feed. In 1964, the Brazilian urban population exceeded the amount of people in rural areas. This demographic change also pushed the demand for food that expanded the consumption of grains.

Finally, after the 1990s, the rise in demand for food from emerging economies increased the demand for vegetable protein and therefore soybean production. The clustering of these several innovations over a period of time, and driven by both supply and demand factors, permitted the expansion of arable land and sustained Brazilian

1. It is a biome quite similar to African savanna that covers an area of 120 million hectares, nearly 22% of Brazil's surface. For a long time, Brazilians farmers had referred to this region as "*campos cerrados*" (or closed and inaccessible land), because of inappropriate soil characteristics (with high acidity and aluminum levels) to sustain agricultural production. From 1955 to 2014, the Cerrado incorporated more than 40 million hectares from only 200 thousand hectares of arable land.

production at international levels of productivity. The outcomes were extraordinary: over a fifty year period, the food production increased more than eight times while the size of population grew around 2.5 times, thus increasing agricultural production per capita. This performance helped to improve domestic food security and boost foreign trade. In 1961, Brazil was a net agricultural importer. Since the 1980s, it has become a net exporter.

According to table 2, GDP per capita has grown substantially in mid-income countries and in emerging economies, such as Brazil, China and India, followed by the rest of world. The world urbanization rate reached 50% in 2009, and the population growth has still been high in low-income countries. That observation points to a demand-pull effect for more agricultural technologies. Countries like Argentina, Brazil, Chile, China, India, and Ethiopia have all boosted world food production.

TABLE 2
Growth rate of GDP per capita, urbanization and population by selected countries and income classification 1965-2012

Indicators	Countries and income stratus	Years			Geometric growth rate		
		1965	1990	2012	1965-1990	1990-2012	1965-2012
GDP per capita (constant 2005 US$)	Argentina	4,161.6	3,968.8	6,195.4[c]	-0.2	2.8[c]	1.0[c]
	Brazil	1,858.8	3,999.4	5,730.2	3.1	1.6	2.4
	Chile	2,623.9	4,121.3	9,430.5	1.8	3.8	2.8
	China	118.4	462.7	3,344.5	5.6	9.4	7.4
	India	244.1	403.1	1,123.2	2.0	4.8	3.3
	Ethiopia	158.3[b]	144.0	273.7	-1.0[b]	3.0	1.8[b]
	France	13,785.6	28,249.5	35,709.1	2.9	1.1	2.0
	Germany	17,463.5[a]	28,775.8	39,273.4	2.5[a]	1.4	1.9[a]
	United States	18,783.3	32,965.6	45,038.2	2.3	1.4	1.9
	Low income	319.4[a]	305.5	440.9	-0.2[a]	1.7	0.8[a]
	Middle income	668.6	1,226.9	2,729.1	2.5	3.7	3.0
	High income	11,364.2	23,064.6	31,927.5	2.9	1.5	2.2
	World	3,620.7	5,856.8	7,844.1	1.9	1.3	1.7
Urban population (% of total)	Argentina	76.4	87.0	91.3	0.5	0.2	0.4
	Brazil	51.0	73.9	84.9	1.5	0.6	1.1
	Chile	71.7	83.3	89.0	0.6	0.3	0.5
	China	18.1	26.4	51.9	1.5	3.1	2.3
	India	18.8	25.5	31.6	1.2	1.0	1.1
	Ethiopia	7.6	12.6	18.2	2.1	1.7	1.9
	France	67.1	74.1	78.8	0.4	0.3	0.3
	Germany	72.0	73.1	74.7	0.1	0.1	0.1
	United States	71.9	75.3	81.1	0.2	0.3	0.3
	Low income	12.4	21.7	29.5	2.3	1.4	1.9
	Middle income	25.6	36.1	49.3	1.4	1.4	1.4
	High income	65.4	74.4	79.8	0.5	0.3	0.4
	World	35.5	42.9	52.5	0.8	0.9	0.8

(Continues)

(Continuation)

Indicators	Countries and income stratus	Years			Geometric growth rate		
		1965	1990	2012	1965-1990	1990-2012	1965-2012
Population (million)	Argentina	22.3	32.6	41.1	1.5	1.1	1.3
	Brazil	84.4	149.6	198.7	2.3	1.3	1.8
	Chile	8.7	13.2	17.5	1.7	1.3	1.5
	China	715.2	1,135.2	1,350.7	1.9	0.8	1.4
	India	498.0	868.9	1,236.7	2.3	1.6	2.0
	Ethiopia	25.0	48.0	91.7	2.6	3.0	2.8
	France	49.9	58.4	65.7	0.6	0.5	0.6
	Germany	76.0	79.4	80.4	0.2	0.1	0.1
	United States	194.3	249.6	313.9	1.0	1.0	1.0
	Low income	264.8	494.6	830.0	2.5	2.4	2.5
	Middle income	2,136.7	3,644.5	4,913.6	2.2	1.4	1.8
	High income	925.9	1,139.8	1,299.5	0.8	0.6	0.7
	World	3,327.4	5,278.8	7,043.1	1.9	1.3	1.6

Source: World Bank (2014).
Notes: a. 1970; b. 1981; and c. 2006.

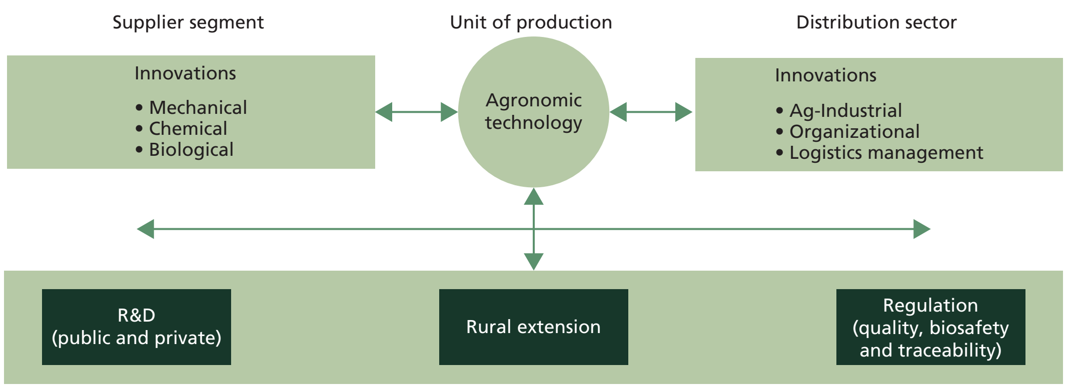
As the Brazilian example demonstrates, both supply and demand pressures have driven the learning response. However, there is no universal solution to how learning is shaped by supply and demand. Many nations, however, have not responded to similar food demand by using Brazil's strategies, so there is a wide discretionary ambit that lies outside any supply-demand law. According to Srinivas (2014, p. 83), "*demand is not a single signal of desire (yes or no) but has several stages and actors in the innovation and production process*". Moreover, the difference between demand and need is multi-fold and complex. Indeed, there are at least four "grades" that shape a learning and innovation environment: "*first, the more traditional economics term 'effective demand'; second, need that is not recognised as a need; third, need recognised as a need but not as a demand; and fourth, recognised but unfulfilled demand*" (Srinivas, 2014, p. 84). A more evolutionary framework would recognize the co-evolution between these different "grades" of need-demand connections in development.

Collective trends and policy push can therefore shape effective demand and generate new demand toward an improved learning feedback process. Governments can also be important lead-users, setting demand conditions in a widespread way. Much of the focus of manufacturing sector studies articulate well the impact of effective demand on learning. In the ideal context, just as in manufacturing, learning in agriculture can also generate positive spillovers from one sub-sector to another. As in the Brazilian case, a cluster of innovations in agriculture spreads: when such agriculture is embedded in an industrial value chain, the spillovers are visible in both farms and firms alike. Market size is usually hypothesized to induce primarily process innovations such as mechanization and different managerial forms of planting. In contrast, user-led (through lead-users' demand) are likely to generate new products, such as high-yield seed varieties and the agricultural liming technique.

4 AGRICULTURAL LEARNING: DISTINCTIVE, YET SIMILAR

While agriculture may be distinct from manufacturing, both are part of an important wider industrial process. Yet the learning systems of agriculture are nevertheless institutionally distinct from those of manufacturing. The innovation process in agriculture that reflects such learning manifests in adoption and diffusion of technology organized through a complex production system to fuel agricultural productive chains. The organization of agricultural activity (see figure 1) is defined in a broad way, involving not only the downward and forward stream of production, but also the system of research, science and technology.

FIGURE 1
Innovation, science and technology in the organization of agricultural activity



Source: Adapted from Vieira Filho (2012).

Note that similar to this diagram, learning in manufacturing also has a supplier segment and a distribution sector. In order to comprehend formal and informal R&D systems, Biggs and Clay (1981) and Biggs (1990) argue that agriculture leads to a pattern of innovation different from that in industry. However, unlike agriculture where the technology is germplasm and our state of knowledge about it, in manufacturing the unit of production is taken to be the business firm. Nevertheless, one could argue that the technology of the firm is not the proto-typical Chandlerian or other firm with R&D or skilled personnel (although these may provide advantages), but that the manufacturing sector's technology is a complex mix of knowledge and routines (Nelson and Winter, 1982). This would highlight some similarities between manufacturing and agriculture. According to Vieira Filho, Campos and Ferreira (2005), and Vieira Filho and Silveira (2011), technical change is understood as a part of a process that begins outside the farm (external knowledge) but is increasingly embodied within the unit of production. Nonetheless, there are also feedback effects from the unit of production that influence the parameters of technological innovations in the supplier industry, thus modifying adoption and diffusion of technology.

However, the biological basis of the difference between agriculture and manufacturing is indeed intimately tied to technology. Germplasm is a technology of a different kind, which exhibits a complex mix of knowledge and routines but of a less recognizable form. The germplasm much more than the technology of a manufacturing firm, is a biological entity that has distinct and localized characteristics vulnerable to far more than human influence alone. In agriculture, the learning process and the transferability of expertise from one region to another are severely limited, thus creating a more differentiated pattern of demand and supply.[2] Manufacturing in contrast affords learning and supply uniformities for many products that can, in principle, generate mass manufacturing solutions across geographies. Climactic variation in agriculture is also at the root of uneven knowledge diffusion from temperate to tropical agriculture both across and within countries. This is partly driven by natural factors but also by policy neglects.

To increase agricultural productivity, institutional changes can incorporate location-specific R&D. When policy (national and regional) includes deliberate engendering of wider absorption and diffusion capabilities, we see gains in the adaptation and dissemination of the technology visible in international comparisons. Ruttan (1986) argues that Brazil, India, and the Philippines (nations of the "Green Revolution") were national examples that developed professional capacity to absorb, transmit, and adapt effectively the knowledge through international research linkages.

This institutional and organizational landscape has been designed to be explicitly different from manufacturing (Ruttan, 1989). The CGIAR[3] global partnership of research organizations for example, are dedicated to agricultural issues with wider developmental goals such as reducing poverty and hunger, improving human health and nutrition, and enhancing ecosystem resilience. CGIAR's structure of inter-public agencies and extension networks, in contrast to manufacturing R&D networks which may have substantial private involvements, is also more narrowly and ambitiously focused on the learning benefits of location-specific advances, and of the diffusion of innovations in very select germplasms.

2. "Industrialized" agricultural operations undertaken in developing countries seemed to point to problems in relative factor prices to guide efficient investment (Johnson and Ruttan, 1994). The lack of systemic national innovation supports also resulted in large-scale agriculture failures.
3. Formerly the Consultative Group on International Agricultural Research.

Late industrial South Korean semi-conductor consortia did share some national attributes with a CGIAR-like agriculture system of cross-organization learning, investment and extension. Therefore, seen in this way, this learning environment selects for how the technology and the vehicle (farm/firm) evolves. If farms and firms are seen as part of an inter-linked institutional environment each supplying the other, it is likely that CGIAR (in wheat or soy) and manufacturing consortia (e.g. semiconductors or automobiles) might both be differently imagined.

For both manufacturing and agriculture, innovations happen along the productive chain. The supplier segment comprises the mechanical, chemical and biological innovations. The distribution comprises the agri-industrial and organizational innovations which manifest in improvements for storage, processing and logistics.[4] The systemic conditions for innovation also point to the need for a more dynamic, endogenous approach. Foster and Rosenzweig (1995) have demonstrated how an agricultural sector with an imperfect knowledge of the management of new seeds developed significant barriers to adoption. Furthermore, that these barriers diminished simultaneously as farmers' experience with the new technologies increased. Cohen and Levinthal (1989)[5] and Vieira Filho and Silveira (2011) also show that the learning process and the absorptive capacity of recognizing new knowledge in agriculture should also incorporate dynamic and endogenous processes.

Given that agriculture and manufacturing sector live side-by-side and agriculture plays a vital human role, what appears to be missing are the Schumpeterian dynamics of learning between farms and firms. In part, as discussed earlier, this gap originates in the differences of how economists represent technology in the two. However, there are a series of outlier innovations even in manufacturing that can be incorporated into learning frameworks more explicitly (Srinivas and Sutz, 2008; Arocena and Sutz, 2010; Kaplinsky, 2011). Not only are there likely many more such innovations in agriculture that have similarly been understudied, but our hunch is that the dynamic gains are under-recognized because of how the relationship between firms and farms is

4. In Brazil, just to give an idea about the size of agricultural chain, the market share of agribusiness varies from 15% to 45%, including all agricultural activity organization. Gasques *et al*. (2004) measured agribusiness market share around 34% of the Brazilian Gross Domestic Product (GDP), which is divided, on average, per 6% for supplier segment, 30% for agriculture, 31% for food industry and 33% for distribution.
5. These authors mention specifically about agriculture the paper written by Evenson and Kislev (1973).

represented. If agricultural learning is distinctive, yet similar, we must have some way to investigate these inter-linkages. We do this next by revisiting two classical models of economic development.

5 LEARNING IN CLASSICAL MODELS OF ECONOMIC DEVELOPMENT[6]

East Asian growth and development has had features central to our argument, as a manufacturing-led and a supply-driven learning analysis. Although manufacturing was in some instances accompanied, even driven, by land reform (Taiwan, for example), there nevertheless was an immense learning process that occurred in manufacturing and which has resulted in a view of East Asian learning as essentially (and perhaps somewhat exclusively) as manufacturing-driven learning.

Our argument is that in the traditional approach, manufacturing is given primacy and agricultural growth is a second best development option. The reason to more clearly see the East Asian analysis as composed of its elements of manufacturing – led learning and especially export-led learning at that, is to recognize the privileged place that manufacturing firms hold in economic development analysis. These situate the wider needs of domestic and export consumers who may remain unconverted to effective demand and both hold (different) under-recognized potential for agriculture investments. Based on this argument, our next contribution is to briefly analyze 2 different two-sector models both of which attempt an improvement on prior classical models and are concerned with capturing a dynamic element of technical change and to economic and regional characteristics. We review them first, and then address some of their learning implications.

6. Davis and Goldberg (1957) conceptualized the term "agribusiness" and tried to explain the articulation between production, supplier sector and consumers. The concern about the chain has brought new dimension of understanding stakeholders' decisions, and it has changed the way of planning actions that interfere the chain as a whole. "*The concept of industrial 'filières' (in English, 'web' or 'cluster'), despite being fairly impressionistic, helps to highlight a system of interdependence based, on the traded side, on input-output relations, and, even more importantly, on the untraded side, on technological interdependences, which are likely to be (...) region-specific and company-specific. In this context, 'chains' of innovations in different interlinked sectors might tend to be reinforcing in 'virtuous circles' affecting both sectoral technological levels and their rates of growth*" (Dosi, 1984, p.288). In an evolutionary approach related to agriculture, the *regional productive chain was described by Vieira Filho, Campos and Ferreira (2005) as the innovation process through the forward and backward linkages in the agribusiness*.

5.1 The Lewis two-sector model

Both supply and demand have effects on learning. Moreover to the degree that remains unconverted into effective demand, learning's developmental effects may be muted. One economic development framework that is well sensitized to the institutional response that mutes an economy's full potential is the "unlimited supply of labor" model (Lewis, 1954). This model is attuned to the dynamic supply-demand relationship and especially the critical role of the capitalist in matching the two. In essence, much of the Lewis model depends on the ability of the capitalist to regulate wages in the "subsistence" sector of the economy. This surplus in the capitalist sector goes towards the profits of businesses, while most (unlimited supply) workers remain outside the sector in subsistence activities, earning what they can.

From a learning standpoint, this model is vastly under-utilized and has considerable potential. Lewis's explanation after all is a deeply institutionalist one that could be extended to incorporate learning institutions. He differentiates among capitalists themselves and thus moves far ahead of a traditional Marxian analysis.

> For the type of capitalist who brings about economic expansion is not the same as the type of employer who treats his employees like retainers. He's more commercially minded, and more conscious of efficiency, cost and profitability. Hence, if our interest is in an expanding capitalist sector, the assumption of profit maximisation is probably a fair approximation of the truth" (Lewis, 1954, p. 146)

Because he is able to differentiate between and within classes, Lewis has the basis for a dynamic learning environment in which different political and financial positions of capitalists can generate diverse conditions for learning and spillovers which can then stitch together sub-systems of the economy. Lewis makes an important point about dynamic efficiencies that can result in showing how many aspects of the economy are institutionally linked together:

> We take account of the fact that the capitalist sector, like the subsistence sector, can also be subdivided. What we have is not one island of expanding capitalist employment, surrounded by a vast sea of subsistence workers, but rather a number of such tiny islands. This is very typical of countries in the early stages of development (*op. cit.*, p. 147).

Lewis also says,

> In backward economies knowledge is one of the scarcest good. Capitalists have experience of certain types of investment, say of trading or plantation agriculture, and not of other types, say manufacturing, and they stick to what they know. So the economy is frequently lopsided in the sense that there is excessive investment in some parts of under-investment in others. [...] Inevitably what one gets are very heavily developed patches of the economy, surrounded by economic darkness (*op. cit.*, p. 147).

Indeed, the power of his framework is that once capitalists and workers are tied together *in specific types of institutional relationships*, it becomes possible to see that a central observation of the model is *the dynamic relationship between firms and farms*. Lewis points out that one of the simpler versions of this model is when peasant farmers cultivate their own land. Migration off the land occurs when wages in the capitalist sector exceeds that of farm wages. Wages in this case simply reflect the average product of farmers. However, when farmers do not own the land and themselves are tenant farmers in high population situations, their net wage can go substantially toward rent and very basic subsistence. The "unlimited supply" of labor then earns minimum earnings that are not directly correlated to the productivity of workers.

Moreover, creating a political economy of learning, Lewis points out that the political implications of the higher wages in the capitalist sector result from the ability of capitalists to hold down the productivity in the subsistence sector.

> Thus, the owners of plantations have no interest in seeing knowledge of new techniques or new seeds conveyed to the peasants, and if they are influential in the government, they will not be found using the influence to expand the facilities for agricultural extension. They will not support proposals for land settlement, and are often instead to be found engaged in turning the peasants off their lands (*op. cit.*, p. 149).

This political economy of learning is dynamic. After all, there are many explanations for why wages in the capitalist sector are much higher than those in the subsistence sector: rents and transport costs explain part of the difference since those in the capitalist sector are often in urban areas with higher costs. However there are other differences in real wages: those that make adjustment to manufacturing over agriculture, of educational differences, and that skills can be learned and are worth rewarding in manufacturing and the socialization of status associated with urban lives and manufacturing themselves require higher wages, and a range of other social economic reasons (see Lewis, 1954, p. 150-151). Indeed, the growth of technical knowledge in the subsistence sector would raise the level of wages there and fundamentally create a downward pressure on capitalist profits.

Our hypothesis is that learning institutions that permeate the economy are disproportionately represented in manufacturing *versus* agriculture. Firms for instance are assumed to require a density of vocational training supports. Agriculture is assumed to require few that learning is hereditary or osmosed, and that farms may not necessarily compete or collaborate in ways similar to firms. This is not only represented in the two-sector model, but it may be exaggerated in important respects thus obscuring the way forward for economic policies. In particular, some subsectors (certain kinds of machine tools and engineering products such as engines, pumps, and tractors) supply manufacturing, utilities, as well as agriculture and form the input basis for products and processes in both. The two-sector model therefore may be more pessimistic about the implications of Schumpeterian emphasis on learning dynamics because it underestimates the degree to which (and the variety of sub-sectors through which) manufacturing and agriculture are linked.

5.2 The induced innovation model

In contrast to Lewis's model, agricultural productivity studies focused on biological hybrids moved towards stricter – and more neoclassical – factor endowment models. These pushed classical economics towards a particular type of learning analysis. Although the induced innovation model was more direct about learning, it was more conservative in its economics. Hayami and Ruttan (1985) studied agricultural development in the United States and Japan, because these countries represented two agricultural stereotypes. First, the United States exemplified labor scarcity. Second, Japan exemplified the impossibility of expanding agricultural frontiers due to extreme land scarcity. In the United States in turn, machinery saved the scarce resource, labor; in Japan, biological improvement extended gains in productivity to offset the constraints imposed by an inelastic supply of land. Both countries therefore provided particular and extreme examples of institutional solutions to limited, geographically-specific, and factor endowments.

The model of induced innovation was an effort to develop an integrated theory of agricultural development and to incorporate technological and institutional changes. However, the interpretation is essentially a neoclassical analysis of displacement of the production frontier with equilibrium points determined by changes in relative prices of inputs, usually a combination that saves labor or capital. The model plots tangent points between isoquants (linear) and isocosts (non-linear). Thus, as regarded by Vieira Filho and Silveira (2012), the shift of the production curve, with changing in relative prices over time, promotes technical change which itself remains as a residual factor. Later Ruttan (1997) recognized the importance of institutional arrangements to pick-up the signs of scarcities, and showed that these signs could govern the relative prices due to induce innovation.

It is worthwhile dwelling on the fact that according to both Lewis (1954) and Hayami and Ruttan (1985), a mechanical innovation can save labor. However, while Lewis (1954) pointed out that a result of such innovations was a decrease in wages directed to industry, Hayami and Ruttan (1985) explained the creation of an innovation related to price signals. Moreover, the effect of innovation on the *interaction* between agriculture and industry is different. To Lewis (1954), the innovation in agriculture can release the labor force to industry. As innovation diffuses more widely the supply curve shifts to the right in the agricultural market, the product price falls, and the producers' surplus profit disappears (the treadmill effect). This process helps industry in urban areas by lowering wage cost.

To Hayami and Ruttan (1985) in contrast, innovation is related to a resource's scarcity and subsequent institutional changes. As you have a scarce resource, there is a demand for innovation. Usually, when one factor is scarce, the relative price compared to other inputs is high. The opportunity cost to innovate decreases in the way of generating new knowledge that saves scarce resources. The stream of new technical inputs must be complemented by investments in education and by efforts to transform institutions. In other words, institutional change is required to increase the agricultural units' absorptive capacity (Cohen and Levinthal, 1989; Vieira Filho and Silvieira, 2011). For Hayami and Ruttan (1985), technical change reflects the progress of science and technology. The adoption rate of a new technology and its autonomous impact on productivity will be strongly influenced by the conditions of resource supply and demand of products. These forces are reflected through the markets of factors and products.

The hypothesis behind the induced innovation model explained that the high agricultural productivity was based on: *i*) the development of a nonagricultural sector capable of transmitting increased productivity to agriculture in the form of cheaper productive factors (such as tractors and chemicals); and *ii*) the capacity of economic environment to generate a virtuous sequence of technical innovations in agriculture that pulls the demand for inputs supplied by the industrial sector. Regarding this model, the demand can create a stimulus in the production of a new technology (demand-pull). At the same time, industry can reply by producing incremental innovation in the existing technology (technology-push).[7]

7. For example, we can specify a demand for more tractors, or a supply of tractors that have better performance. If agricultural units increase the use of tractor (or any other input), there will be an outward shift in the demand curve. If there is an introduction of a tractor with new technical specificities, there will be a downward shift in the tractor's supply curve that leads to an intersection with the demand curve at a lower price than before. Both changes can save labor or even land, depending on what kind of technology was incorporated.

Although the analytical framework presented by the induced innovation thus far is quite close to much of neo-Schumpeterian evolutionary theory, it is important to make some observations. Although technical change can be influenced by changes in relative prices, nonetheless the automatic replacement of a technical input by the scarce factor *does not proceed* in the absence of institutional changes. In this sense, the theory of induced innovation is subject to strong institutionalist assumptions because the induced bias of technical change is more complex than an equilibrium adjustment, a fact well recognized by the original authors. In contrast to Hayami and Ruttan's framework, a more explicitly evolutionary approach emphasizes a much more substantial feedback effect from learning. Technical changes are provided by the linkages through the entire agricultural chain showing a feedback effect amongst supplier segment, research centers and unit of production (see Sahal, 1985; Dosi, 1984; 1988; Chiaromonte and Dosi, 1992; Mowery and Rosenberg, 2005). Thus, unlike an approach based only on relative prices, technological change in agriculture depends on the technological trajectory, as observed by Salles Filho (1993), and the accumulation of knowledge, as seen by Vieira Filho and Silveira (2011). Indeed, others (Srinivas and Sutz, 2008) argue that scarcity-induced innovations rather than call on a traditional factor-scarcity explanation must make explicit the cognitive and structural assumptions of technology transfer on which they depend. This allows a more careful understanding of how different sub-systems of the economy (Lewis's "islands") may live side by side, with policy discourse disproportionately weighting some types of technology transfer and learning, and rejecting others.

5.3 Assumptions of the staged models in economic development history

Both Lewis (1954) and Hayami and Ruttan's collective works are mostly focused on a two-sector model. In general the "stages" models of economic development include a primary sector (agriculture), and a secondary sector (manufacturing, and some utilities, as well as extractive industry). The two-sector model is directed at understanding first and foremost a transition ("economic development") between a primary sector of agriculture and the secondary sector focused mostly on manufacturing. An economy in a two-sector model is transitioning between agriculture to manufacturing; the tertiary (services) sector is something of an afterthought (although where it is present, we might refer to this as a staged three-sector model instead).

The two-sector model implies several simplifications which may be necessary for some analytical purposes, but which arguably have mistaken simplifications when referring to *learning*. These distract from how we might insert Schumpeterian learning into sector models. It is thus worth making these assumptions explicit:

1. Manufacturing is seen as preferable to agriculture, and follows from agriculture. In other words, capitalists are those who see the manufacturing sector as the mechanism by which productivity rates are higher and profits more dependable;
2. Moreover learning opportunities are concentrated in the manufacturing sector as capitalists crowd to it. Whether this is a symptom or a cause of such concentration is not clearly specified and could be a dynamic that explains directionality;
3. The behavior of capitalists itself influences the view of agriculture as a subsistence activity that supplies workers and explains the rise of manufacturing;
4. The stage model does not much allow for simultaneity: while agriculture and manufacturing can live side-by-side (after all this is the two sector model's basis); the staging privileges manufacturing over agriculture and services becomes a tertiary stage, often where manufacturing and services become phased in different ways (this is precisely one of the issues now concerning those studying middle income traps); and
5. Finally the stage model is closely tied to specific explanations of rural-urban migration through assuming differential productivity and learning in the agriculture and manufacturing.

Instead, if we take the stages as a point of enquiry rather than departure, we might ask how we can accommodate real-life economic development trajectories with the following characteristics:

1. In most economies, agriculture, manufacturing (as well as utilities and extractive industries), and services live side-by-side;
2. In no economy does manufacturing comprise the bulk of the economy for all time, although western and northern Europe, the United States, and most recently China, are the closest examples we have;
3. In many countries, both industrializing and industrialized economies – agriculture continues to play an important role. Although its function relative to contributions to GDP can be debated, it is clear that in many developing economies it plays a crucial employment and political role. In industrialized economies although many fewer people are employed in agriculture, its contributions to GDP as well as culture and politics continue to be important (the heated debates about agricultural subsidies in Europe and Japan are evidence);
4. Most economies have a wide array of services contributions to the economy. Indeed, the rise of Indian IT services and Irish IT and accounting are good examples of how crucial services can be to learning and knock-on effects in

both manufacturing as well as agriculture.[8] Even services in the informal economy that are often seen to be low value-added can add up to a substantial portion of the GDP. These may include both low and high productivity and value addition in street vending and food retail, to furniture, pottery, home-based work in the garment sector, to many construction activities and business process subsectors);

5. Also many case studies of manufacturing sectors themselves have contributed to a neo-Schumpeterian revival on the importance of learning in economic development. These cases show us that the benefits of dynamic learning models are not relegated to manufacturing alone;
6. Many economic scholars (including some recently studying the so-called Middle Income Trap) have returned to the mixed linkages between manufacturing and services and the gains to be had in learning across both.

For these reasons, we argue that it is vital therefore to look more systematically at the cross sector learning between agriculture and manufacturing, especially because there is no clearly staged directionality from agriculture to manufacturing in economic development history.

What does economic development history tell us are possible combinations of agriculture and manufacturing that might inject some Schumpeterian optimism into the relationship between these two sectors and move away from three sector staged models? There are several permutations of how economic development histories have actually combined manufacturing and agriculture even in what can be called the "industrialization" path, which is more the exception than the rule in economic development history period.[9]

A common attribute for industrialization is to replace imports of manufactured consumer goods through domestic manufacturing impetus (this is more popularly known as import-substituting industrialization – ISI). Prebisch (2000) was remarkable for describing Latin America's underdevelopment as over-dependence on primary exports subjected to macroeconomic volatilities, while the central countries exported industrialized goods. From the perspective of international trade, developing economies

8. Information Technology represents a segment of industry, which includes computer (software and hardware), telecommunications and data management.
9. This discussion is taken from Griffin (1989).

transferred earnings to developed countries, suppressing their own industrialization. According to Tavares (1972), this stimulated the ISI as well as increased protectionism in order to reduce manufacturing imports and to promote domestic production.

Even though state investment in state ownership has often been seen as a primary attribute of ISI, in reality much of the focus on manufacturing is driven by the private sector, with the state playing much more of regulatory and incentive role. ISI itself over-focused on manufacturing and tended to pay great attention to certain policy instruments. These included trade policies, which changed the relative inter-sectoral composition of output as well as the intra-industry composition. ISI furthermore skewed policies in the direction of manufacturing and away from agriculture, but it also focused much more on domestic consumption strategies. ISI also created incentives that affected relative factor proportions in manufacturing that then had spillover effects in agriculture and services.

To understand why growth began earlier in some countries than in others, Griffin (1989) tried to classify different strategies and incentives for economic development. The relative shift of income between factors of production then boosted manufacturing, boosted industrial income within GDP, and lowered the rents obtained in export agriculture and mining. Furthermore these investment priorities shifted the distribution of income and wealth between rural and urban areas. This occurred for a range of reasons, but complicated the abilities of different consumers in the push to creating effective demand. ISI could be seen then as causing substantial disparities in the strategies of producers to seek out consumers who can pay. The implicit disparities created by ISI not only skewed agriculture versus manufacturing, it also distorted the types of learning and manufacturing strategies that sought out higher income customers, and which might push towards productivity relationships in urban areas.

Taken as a whole, industrialization as a development path thus appeared to have a clear approach to privileging the transition from agriculture to manufacturing (and thus a complex rural-urban mix), and to privileging specific types of learning within manufacturing. In reality, as shown by figure 2, industrialization itself was made up by three distinct country strategies, which could be generalized to bring out distinct "learning flavors".

FIGURE 2
Three variants in industrialization paths via ISI

Nation	Industrialization path		
Brazil	Import substitute consumer goods →	Develop a capital goods industry →	Export manufactured goods
India	Establish capital and intermediate goods industries →	Successively open the economy →	Export manufactured goods
South Korea	Establish alignment between domestic and international prices as much as possible →		Export manufactured goods

Source: Adapted from Griffin (1989).

These diverse paths of industrialization include a range of technological learning types: invention, discovery, (Freeman and Perez, 1988; Dosi, 1988) imitation, reverse engineering (Kim, 1997); learning by doing (Arrow, 1962; 1963); learning by using (Lundvall, 1985); training with equipment that embodies innovation; "learning by proving" in response to external technical standards (Srinivas, 2014); and "learning by monitoring" in response to compliance and inspection (Sabel, 1993). In all three country strategy cases, the type and degree of learning involved is quite different. As Lewis himself pointed out, even within manufacturing, there are many subsectors of capitalist investment (consumer, capital and intermediate goods; labor-intensive *versus* more capital intensive, etc.). The hidden links between manufacturing and agriculture provoke questions even within the three diverse paths of ISI of how one strategy can interfere in another. Lall (1982, 1993) also points to how learning with capital equipment was crucial in feeding a wide variety of firms in developing countries.

With the emergence of agribusiness, since 1970, the vision of "agricultural functions" as a progressively regressive activity by industrialization has been broken. The paradox established showed there were a great number of countries (some from Latin America and other from Asia) with high indexes of human development that would be considered an "agro-industrial" foundation, meaning that some countries were capable of conducting diversification processes and having agribusiness as their core. In most of these countries from 1980, the relation of the terms of trade on the international market became favorable which fragmented the argument of Prebisch that the industrialization of Latin America would not be compatible with the efficient development of primary production.[10] As viewed in table 3, one can observe a comparison of some economic indicators related to agricultural development. In general, even though the agriculture's market share has reduced over time, the use of technology has increased and consequently has improved labor productivity.

TABLE 3
Indicators of technological change in world agriculture by selected countries and income stratification 1962-2012

Indicators	Countries and income stratus	Years			Geometric growth rate			Remarks and comments
		1965	1990	2012	1965-1990	1990-2012	1965-2012	
Rural population (% of total population)	Argentina	23.6	13.0	8.7	-2.4	-1.8	-2.1	Going down significantly in all countries
	Brazil	49.0	26.1	15.1	-2.5	-2.5	-2.5	
	Chile	28.3	16.7	11.0	-2.1	-1.9	-2.0	
	China	81.9	73.6	48.1	-0.4	-1.9	-1.1	
	India	81.2	74.5	68.4	-0.3	-0.4	-0.4	
	Korea. Dem. Rep.	54.9	41.6	39.6	-1.1	-0.2	-0.7	
	Ethiopia	92.4	87.4	81.8	-0.2	-0.3	-0.3	
	France	32.9	25.9	21.2	-0.9	-0.9	-0.9	
	Germany	28.0	26.9	25.3	-0.2	-0.3	-0.2	
	United States	28.1	24.7	18.9	-0.5	-1.2	-0.8	
	Low income	87.6	78.3	70.5	-0.5	-0.5	-0.5	
	Middle income	74.4	63.9	50.7	-0.6	-1.0	-0.8	
	High income	34.6	25.6	20.2	-1.2	-1.1	-1.1	
	World	64.5	57.1	47.5	-0.5	-0.8	-0.6	
Agricultural machinery. tractors (thousand)	Argentina	155.0	264.5	244.3[c]	2.2	-0.7	1.2	Except the United States and Germany, all countries have increased the number of agricultural machinery. Particularly in the case of Brazil, this increase was almost 7 times higher than approximately 50 years ago
	Brazil	114.0	728.8	788.1[c]	7.7	0.5	4.8	
	Chile	33.8	35.8	53.9[c]	0.2	2.6	1.1	
	China	73.0	824.1	989.1[c]	10.2	1.8	7.7	
	India	48.0	988.1	2091.0[c]	12.9	7.8	11.4	
	Korea. Dem. Rep.	13.0	67.5[b]	-	9.1	-	-	
	France	996.4	1440.0	1176.4[c]	1.5	-1.3	0.4	
	Germany	1,288.4	1567.5	989.5[c]	0.8	-4.5	-0.8	
	United States	4,800.0	4426.7	4389.8[c]	-0.3	0.0	-0.2	
	Low income	63.3	66.9	95.6[b]	0.2	4.6	1.3	
	Middle income	1,104.5	5,411.1	8,182.6[c]	6.6	4.2	5.9	
	High income	10,382.9	15,708.7	16,768.8[c]	1.7	0.7	1.4	
	World	11,550.6	21,186.6	25,054.1[c]	2.5	1.7	2.2	

(Continues)

10. For example, on one hand, a laptop (IBM ThinkPad 700, Windows 3.1, 25 MHz 486 processor, 120 MB hard disk drive, 10.4 "display, 3 kg) in 1992 had cost US$ 4.350,00. In 2013, a very similar laptop (Lenovo ThinkPad Edge, Windows 7, Intel® i3 (2.3 GHz), 14.1" display, 320 GB HD, 3 kg) could be purchased for US$ 700,00. On the other hand, in 1992, a price of one ton of soybean had cost US$ 209,00. In 2012, the same ton of soybean could be bought by US$ 538,00. This represents the China effect. The increase of Chinese manufacturing has changed the economic environment. Thus, we can say that there is a kind of *Prebisch paradox*.

(Continuation)

Indicators	Countries and income stratus	Years			Geometric growth rate			Remarks and comments
		1965	1990	2012	1965-1990	1990-2012	1965-2012	
Arable land (million hectares)	Argentina	20.5	26.6	39.3	1.1	1.8	1.4	On one hand, it has increased in Argentina and Brazil. On the other hand, it has reduced in Chile, France, Germany and the United States. Other remained almost the same
	Brazil	28.0	50.7	72.6	2.4	1.6	2.0	
	Chile	3.7	2.8	1.3	-1.1	-3.3	-2.2	
	China	101.7	123.8	105.9	0.8	-0.7	0.1	
	India	158.2	163.5	156.2	0.1	-0.2	0.0	
	Korea. Dem. Rep.	2.2	2.3	2.4	0.2	0.1	0.2	
	Ethiopia	12.0	10.8	15.3	-0.4	1.6	0.5	
	France	18.8	17.8	18.3	-0.2	0.1	-0.1	
	Germany	12.2	12.0	11.8	-0.1	-0.1	-0.1	
	United States	177.0	185.7	155.1	0.2	-0.8	-0.3	
Crop production index (2004-2006 = 100)	Argentina	28.1	53.8	108.7	2.6	3.3	2.9	There was a general increase, but we can see higher growth in developing countries than in developed countries
	Brazil	29.3	59.0	130.6	2.8	3.7	3.2	
	Chile	28.6	60.8	112.7	3.1	2.8	3.0	
	China	23.1	55.7	129.9	3.6	3.9	3.7	
	India	34.5	72.7	131.2	3.0	2.7	2.9	
	Korea. Dem. Rep.	44.4	98.5	92.2	3.2	-0.3	1.6	
	Ethiopia	59.4	52.5[b]	152.2	-0.4	5.8	2.0	
	France	80.0	96.8	96.6	0.8	0.0	0.4	
	Germany	79.7	93.3	97.1	0.6	0.2	0.4	
	United States	48.2	79.4	97.1	2.0	0.9	1.5	
	Low income	38.1	64.8	130.1	2.1	3.2	2.6	
	Middle income	28.9	62.1	124.4	3.1	3.2	3.2	
	High income	59.7	87.1	98.3	1.5	0.6	1.1	
	World	36.8	68.2	118.2	2.5	2.5	2.5	
Livestock production index (2004-2006 = 100)	Argentina	60.2	84.3	102.6	1.4	0.9	1.1	Widespread growth with strong growth in China and Brazil followed by Chile and India
	Brazil	16.0	44.9	121.7	4.2	4.6	4.4	
	Chile	28.4	55.5	114.8	2.7	3.4	3.0	
	China	9.0	40.1	122.5	6.2	5.2	5.7	
	India	24.8	60.9	127.9	3.7	3.4	3.6	
	Korea. Dem. Rep.	32.2	97.9	103.3	4.6	0.2	2.5	
	Ethiopia	65.7	53.5[b]	126.2	-0.7	4.6	1.4	
	France	72.1	99.0	100.2	1.3	0.1	0.7	
	Germany	79.9	114.5	109.7	1.5	-0.2	0.7	
	United States	59.2	78.7	107.2	1.1	1.4	1.3	
	Low income	36.9	63.4	125.9	2.2	3.2	2.6	
	Middle income	20.9	53.9	122.5	3.9	3.8	3.8	
	High income	59.2	87.7	105.4	1.6	0.8	1.2	
	World	36.7	67.7	115.5	2.5	2.5	2.5	

(Continues)

(Continuation)

Indicators	Countries and income stratus	Years			Geometric growth rate			Remarks and comments
		1965	1990	2012	1965-1990	1990-2012	1965-2012	
Cereal yield (kg per hectare)	Argentina	1,403.2	2,232.2	4,136.4	1.9	2.8	2.3	There was a strong growth in Argentina, Brazil, Chile, China, India and Ethiopia. Followed by moderate growth in other countries. However, the highest yields can be found in developed countries, such as France and Germany
	Brazil	1,428.3	1,755.1	4,584.5	0.8	4.5	2.5	
	Chile	1,691.9	3,619.7	6,229.6	3.1	2.5	2.8	
	China	1,746.5	4,320.9	5,823.5	3.7	1.4	2.6	
	India	854.4	1,891.2	3,020.5	3.2	2.2	2.7	
	Korea. Dem. Rep.	2,539.0	3,923.4	3,832.9	1.8	-0.1	0.9	
	Ethiopia	732.3	1,238.1	2,046.8	2.1	2.3	2.2	
	France	3,106.5	6,082.6	7,523.8	2.7	1.0	1.9	
	Germany	2,852.2	5,411.1	6,899.9	2.6	1.1	1.9	
	United States	3,040.8	4,755.1	5,924.8	1.8	1.0	1.4	
	Low income	1,169.9	1,539.0	2,127.4	1.1	1.5	1.3	
	Middle income	1,276.4	2,567.3	3,635.6	2.8	1.6	2.3	
	High income	2,533.3	4,111.4	4,403.9	2.0	0.3	1.2	
	World	1,620.0	2,867.4	3,639.5	2.3	1.1	1.7	
Agriculture value added per worker (constant 2005 US$)	Argentina	7,037.0[a]	7,175.0	12,064.8[c]	0.2	3.3	2.1	Labor productivity has been increased in general. It is worth noting that, according to the data presented, the index has raised more than four times in France and Brazil, respectively. It is still small in low-income countries and in Ethiopia
	Brazil	1,226.5[a]	1,828.0	5,045.4	4.1	4.7	4.5	
	Chile	2,278.0[a]	3,223.7	6,491.7	3.5	3.2	3.3	
	China	223.9[a]	321.8	749.6	3.7	3.9	3.8	
	India	386.8[a]	458.8	672.1	1.7	1.8	1.7	
	Ethiopia	-	179.9[b]	257.1	-	1.9	-	
	France	12,007.2[a]	23,374.3	72,440.0	6.9	5.3	5.8	
	Germany	-	20,329.1[b]	34,243.4	-	2.5	-	
	United States	-	31,566.1[b]	63,268.7	-	4.7	-	
	Low income	263.9[a]	268.2	345.5	0.4	1.2	1.0	
	Middle income	503.6[a]	588.9	1,040.7	1.6	2.6	2.3	
	High income	-	11,462.9[b]	24,277.9	-	4.5	-	
	World	651.9[a]	767.2	1339.1	1.6	2.6	2.3	

Source: World Bank (2014).
Notes: a. 1980s; b. 1990s; and c. 2000s.

Indeed the “Green Revolution” strategy (in reality multiple sub-strategies) was pursued in both India and Brazil to address low productivity of labor in agriculture while also pursuing the wider momentum of an “industrialization” approach. For both countries, the Green Revolution revisited two sector models in order to boost productivity in agriculture and rural areas. Yet, technical change alone in agriculture is insufficient when extracted from a wider institutional redesign for development:

> The weakness of the original green revolution strategy, and even of the revised strategy, is that it tries to substitute technical change and agricultural expansion for institutional reform and direct measures to improve the distribution of income and productive assets in rural areas (Griffin, 1989, p. 160).

6 CONSIDERATIONS AND IMPLICATIONS

Both the labor surplus (Lewis) and the induced innovation (Hayami and Ruttan) models recognize that demand plays a vital role in shaping agriculture and manufacturing. The real challenge therefore for development theories perhaps is to view the manufacturing export strategy that has so much benefited South Korea, Japan, or China, as not an inevitable growth trajectory, but as *a choice between attention to manufacturing versus agricultural exports*. These are issues raised earlier in the land reform literatures for example. Although the gains from learning in export-led manufacturing deserve attention of their own, we do know that agriculture-manufacturing links have been under-studied. Sub-sectors such as machine tools and farm equipment for instance, can act as crucial sub-sector links between what has been traditionally seen as a primary/subsistence sector and a secondary/capitalist or more productive sector. In reality, important suppliers and services feed both sectors with substantial learning spillovers that cross agriculture and manufacturing, and hence also rural and urban institutions.

On the static view, the two-sector model with an unlimited supply of labor may ignore the implications of a Schumpeterian approach once it considers a weak correlation amongst manufacturing and agricultural production linkages. The definition of agricultural activities as a supplier-dominated sector is also an overly restrictive assumption as it implies that technological change would be residual. Agriculture cannot be understood as a sector that imports exogenous technology. It is more than a buying trajectory. Yet, the labor surplus model being fundamentally an institutionalist one, has the potential to be fruitfully extended into the domain of learning because it recognizes actors, politics, and cultural timeframes that shape the imperatives for skills adaptation and absorption.

Theories of learning have considerable potential for understanding both manufacturing and agriculture because of the dynamic approach to technical change, but we are more cautious about how such theories can be deployed in policy design. Looking at the Induced Innovation model, the process of innovation is primarily induced by a differentiation in relative prices. The model explains the direction of technical change in agriculture. Nonetheless, it assumes that the market equilibrium is achieved quite instantaneously after the variation of relative prices. If it is true, the capital mobility should be perfect. In this sense, it is more conservative in its developmental implications than the Lewis model, and perhaps more restrictive and orthodox in its implications for the design of realistic economic policy instruments. These contrasts and comparisons are preliminary observations, and we hope as the research progresses we will be able to combine empirical and theoretical insights more systematically to address the scope of these very rich analytical models.

The issues discussed here are far from academic. These issues have become ever more crucial in the era of climate change, the pressures of industrial growth, food scarcity, employment opportunities, and fluctuations in commodities trade. Furthermore, in the past few decades, land has become ever scarcer which sets limits to more sustainable and efficient farming. Moreover, the GDP share of industry has increased in China and India even while both these economies have retained a large share in agriculture. In addition, over the past few decades a demand-pull effect for agricultural technologies supplied by industrial sector has contributed to boost the world food production in countries like Argentina, Brazil, Chile, China and India, where the national innovation system has played important role in both agriculture and manufacturing (although it is debatable how much they have tried to bring them together). Several African countries are unlikely to follow an economic transition that moves straightforwardly from agriculture to manufacturing and certainly not in the proportions we have assumed for Europe and the United States. They are also unlikely to follow the different trajectories of a Brazil or India whose own agriculture-manufacturing mix have substantial differences.

There is therefore much more remaining to be done to elucidate a more formal rendition of the extension of such models and to consider what types of methods might realistically capture the varied types of learning and innovation spill-overs occurring between agriculture and manufacturing. For one, there are important skills implications which underscore the human dimension of education and training, and the institutional mechanisms to job transitions. For another, there are important spatial repercussions-shaping the outcomes of urban or rural development-based on how agriculture and industry connect or do not. This will undoubtedly shape how urban-rural migration occurs, and the comparative productive advantage of situating agriculture in rural areas versus cities, or agglomeration advantages of infrastructure investments that benefit both agriculture and manufacturing (such as energy and water systems). Both of these are debates that are very much alive and for which answers are needed.

In summary, the analysis here underscores the instinct that any institutional redesign that remains true to a neo-Schumpeterian tradition rooted in learning gains would: *i*) reject a single direction of economic growth from agriculture toward manufacture, with former supplying the latter; *ii*) boost shared supply chain learning across manufacturing and agriculture in specific sub-sector segments with important development implications; *iii*) find more robust analytical ways of connecting learning, wages, and productivity increases that are more dynamic and co-evolutionary in the two sectors (and possibly the tertiary services sector); and *iv*) embrace more heterodoxy in the types of evidence and methods used to analyze inter-linked sub-sectors from machine tools to engine suppliers. We see the framing here and the early exploration of contrasting analytical models of learning as an important first step in this direction.

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