Strategic pragmatism in production transformation: production capability domains, structural composition and intermediate institutions

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Introduction

Production transformation is gradually re-acquiring a central place in development and policy debates, both in industrialised and catching up economies. Even international organisations traditionally focused on poverty reduction, such as UNDP, are searching for a new 'developmentalist synthesis' (Andreoni, 2015a). An increasing number of development economists are also rediscovering and embracing a view of development as "a process that links micro learning dynamics, economy-wide accumulation of technological capabilities and industrial development" (Cimoli et al., 2009: 543). Indeed the idea that production transformation and, thus, micro-learning dynamics in production, are the fundamental triggers of countries' structural change was the dominant view amongst classical development economists such as Albert Hirschman, Nicholas Kaldor and Simon Kuznets.

This new emphasis on production has been accompanied by a more open debate on the role of industrial policies as well as the recognition that they have been widely implemented by today's industrialised economies and fast catching-up countries (Chang, et al., 2013; Andreoni, 2015b). While the 1990s debate on industrial policies was mainly focused on its rationales--the 'why of industrial policy'--economists have been increasingly asked now to investigate the specific industrial policy instruments and institutions--namely, the 'what' and the 'how'. In this regard, while certain contributions, such as the product space approach (PS) and the Growth Identification and Facilitation (GIF) approach, have been well received in the mainstream debates, their intrinsic methodological and policy limitations have remained too often unnoticed.

This paper aims at disentangling the problems associated with simplistic approaches to production transformation and challenging their limited scope for policy design and implementation. On this basis, the paper suggests a more strategic and pragmatic approach to production transformation. This approach is grounded in the reality of production capabilities, the technological linkages underpinning product-relatedness and the compositional features of production structures. The analysis builds on a detailed--historical, context-specific and engineering-based--knowledge of successful experiences of production transformation (see Andreoni and Chang, 2014; Chang, et al. 2014; Andreoni, 2015b).

Going beyond the fantasies of ungrounded approaches, an adherence to 'strategic pragmatism' in production transformation policies suggests focusing on the following three issues.

Firstly, production transformation is about learning and selective attempts to develop complementary production capabilities. Thus, the so-called 'self-discovery' of new production opportunities should not be understood as an accident or self-emerging phenomenon. On the contrary, it should be seen as the result of purposeful and strategic attempts to create and capture value opportunities in the domestic market and within international manufacturing niches.

Secondly, learning to industrialise is a costly process. In order to pay the bill of production transformation, existing sectorial strengths in broadly defined low-tech sectors can be used as invaluable factors of change. Not only do agricultural and agri-tech sectors play a critical macro-balancing role throughout the industrialisation process (e.g., affecting the BOP, employment, internal demand and quantitative linkages), but these sectors can also be transformed as a result of the manufacturing development process itself. In other words, production transformation is an inter-sectoral process, involving cumulative and circular causation dynamics (Andreoni, 2011). As a result, industrial policy packages should include a mix of import substitution (IS) and export promotion (EP) policies targeting different sectors/tasks and their unfolding relationships.

Thirdly, industrial learning requires specific ingredients. Black-box approaches to production focus on generic input factors such as labour, technological knowledge and capital. The different possible ways in which these factors are combined and transformed in effective and innovative forms--i.e., through production and learning processes--are not understood. Production transformation in sectors and specific stages of sectoral value chains requires specific capabilities and differing types of technologies.

Given the semi-public character of some of these technologies, in successful industrialising countries they have been often provided by a variety of public (or public-private) extension services and intermediate institutions. These intermediate institutions can play a pivotal role in the national system of innovation of a developing country. They can translate basic research into applied industrial knowledge, provide specific technologies for product upgrading and certification and identify new market and product opportunities. The overall effect of these institutions is to increase the collective efficiency of a transforming production system.

The paper investigates these three issues and concludes by drawing out a number of key policy issues in the context of Ethiopia.

The product space and the 'normal' production structure

Policy makers engaged in the design of selective industrial policies face a fundamental dilemma (Lin and Chang, 2009). In a nutshell, they need to decide to what extent they want to defy their comparative advantage – i.e., how far they want to deviate from it--and what are the competitive production activities that they want to enhance--i.e., along what sectoral or product trajectories do they want to develop their country. Of course defying a country's comparative advantage requires a strategic political vision and an appropriate mix of industrial, trade and technology policies. Moreover, the identification of sectoral or product-related development trajectories results from the consideration of various factors, including the country's existing endowment of resources and-- more critically--its production capabilities, the degree of relatedness between existing production capabilities and the ones required to perform the new production activities selected, and, finally, the international (and domestic) market space and standards as well as the levels of internal effective demand. The first two factors refer to conditions of production and technical feasibility, while the latter is a more strategic problem related to the international (but also domestic) market structure and nature of competition.

Over the last decade two approaches--the Product Space (PS) and the Growth Identification and Facilitation (GIF) approaches—have become particularly popular exactly because they promise to provide policymakers with answers to these dilemmas and challenges. In reviewing these approaches and identifying their limitations, particular emphasis will be assigned to the PS methodology and its limitations.

The Product Space approach

The PS approach offers a network representation, i.e., the product space, of countries' production structure based on extensive and disaggregated information on products that enter international markets. This approach has developed out of an increasingly rich literature on product sophistication and economic complexity (Lall et al. 2005; Hausmann et al. 2007; Hidalgo and Hausmann 2009; and Felipe et al. 2010; see also UNIDO 2009).

Despite a number of differences, these contributions share a common analytical starting point, that is:

- The complexity/sophistication of a product is a function of the production capabilities required for its manufacture;
- Exported goods are (assumed to be) more sophisticated, the higher the average income of the exporter;
- By examining countries' export basket we can infer the degree of complexity/sophistication of a country's technological and production structure (based on another assumption);

Despite the fact that the Sophistication index developed by Lall et al. (2005) was the first to appear in the literature, the PS approach emerged as a refinement of the PRODY/EXPY indices developed by the Harvard Research Group on Economic Complexity.

The PRODY/EXPY indices developed by Hausmann et al. (2007: 2) are rooted in the idea that 'countries become what they produce'. This means that economic development is mainly a process of learning how to produce (and export) increasingly complex/sophisticated products. In other words, it is a process of building and accumulating production capabilities. The PRODY was developed in this context as a quantitative index that ranks traded goods according to the income levels of the countries that export them. For each product k, the $PRODY_k$ is calculated as a weighted average of the per capita income of the countries exporting the product.

Country *j* has a GDP per capita equal to Y_j while its total exports are equal to the sum of products *l* in the overall export basket, $X_j = \Sigma_j x_{jl}$. In the PRODY the weight is the index of revealed comparative advantage (RCA) and is calculated as the ratio of the value-share of the product in a country's overall export basket (x_{jk}/ X_j) to the sum of all value-shares across all countries exporting that product $\Sigma_j (x_{jk}/ X_j)$. The PRODY is measured in 2005 PPP \$. At the country level, the EXPY index is simply calculated as a weighted average of the complexity of products exported by the country (measured by the PRODY Index). The weight is the share of the product in the country's export basket.

$$\text{PRODY}_k = \sum_j \frac{(x_{jk}/X_j)}{\sum_j (x_{jk}/X_j)} Y_j. \qquad \text{EXPY}_i =_l \left(\frac{x_{il}}{X_i}\right) \text{PRODY}_l.$$

More recently the 'method of reflections' was proposed as a way of solving a fundamental problem of 'circularity' underpinning the PRODY/EXPY analysis, that is, "rich countries export rich-countries products" (Hidalgo and Hausmann 2009). This problem arises from the fact that the degree of complexity/sophistication of a given product is extrapolated from an 'income content' measure, rather than from an 'engineering content' measure (as also recognised in the same literature, see for example Felipe et al. 2010).

The 'method of reflections' aimed to separate the information derived from income levels and those arising from the network structure of countries and the products that they exported. The authors have explained the idea behind this new method by making an analogy with Lego models. Each production capability that a country possesses is regarded as a Lego piece in that country's 'Lego box'. Countries will only be able to make those products for which they have the necessary production capabilities (Lego pieces). Thus, countries' diversification in production (and export) depends on the limited set of activities that their production capabilities allow them to perform.

As certain commodities require special and exclusive production capabilities, we can expect that some products are exported by fewer countries (i.e., are less ubiquitous) than others.

This observation has been empirically tested by representing the network of relatedness between products – i.e., the *product space* (Hidalgo et. al 2007; Hidalgo and Hausmann 2009).

Network analysis has shown that "countries tend to move to goods close to those they are currently specialised in, allowing nations in more connected parts of the product space to upgrade their exports basket more quickly" (Hidalgo et. al 2007:1)[1]. Given this framework, Hidalgo and Hausmann (2009:173) develop two complexity measures for countries and products:

- *Diversification*: the number of products that a country exports with RCA

$$k_{c,0} = \sum_{p} M_{cp},$$

- *Ubiquity*: the number of countries that export the product with RCA

$$k_{p,0} = \sum_{c} M_{cp}.$$

with *c* denoting the country, *p* the product and $M_{cp} = 1$ if country c exports product p with RCA, otherwise $M_{cp} = 0$.

By calculating these two measures jointly and iteratively the two measures of complexity are refined step by step as they take into account the information from previous iterations.

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_{p} M_{cp} k_{p,N-1}, \qquad k_{p,N} = \frac{1}{k_{p,0}} \sum_{c} M_{cp} k_{c,N-1}, \qquad \textit{for } N \geq 1$$

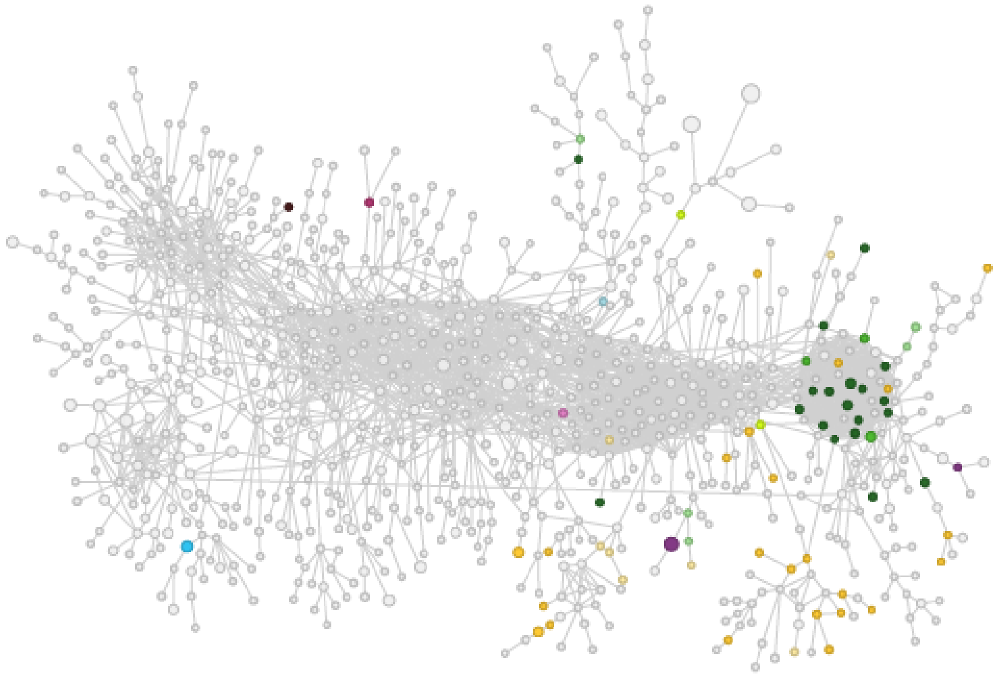
The results obtained by adopting this methodology are explained in the theoretical framework developed by Hausmann and Hidalgo (2010)[2]. Their model does not simply show that countries with a limited set of capabilities will be able to make few products. It also demonstrates that the process of the accumulation of additional capabilities is characterised by increasing returns dynamics: "the likelihood that a new capability will be able to synergise with existing capabilities and become useful for the production of a new

[1] This approach builds on the same intuition that we already find in Richardson (1972) who observes that there are products whose embedded production capabilities can be more easily redeployed for performing *similar* production activities, while other production capabilities (being quite exclusive) can be used only in a limited range of production processes (see Andreoni, 2014).

[2] A number of methodological and mathematical fallacies in this approach have been recently discussed in Pietronero (2015; forthcoming).

product is low in the absence of the other requisite capabilities" (Hausmann and Hidalgo 2010:25). In contrast, countries with a broader set of available capabilities greatly benefit from the acquisition of a new capability since they can combine this capability with the other capabilities that they possess. Figure 1 provides an example of the product space for Ethiopia in 2012.

Figure 1: Product space of Ethiopia (2012)



Source: http://atlas.media.mit.edu/explore/network/hs/export/eth/all/show/2012/

The method of reflection seems to be a powerful tool for overcoming the 'circularity problem' affecting the PRODY index. However, this methodology remains an indirect measure of a country's production capabilities based only on trade data and output variables. As a result its policy relevance is limited and some of the results obtainable do not pass the test of data triangulation.

Firstly, the product space allows us to establish that, given a certain country's export basket, it has to be endowed with a certain number of capabilities. However, no explanation is provided of what these capabilities are, what their engineering content is and how (and in what proportion) they are combined to obtain a certain product. In other words, these metrics have no technological content and do not reflect the reality of production capabilities and production structures in the country. Rather, their existence is simply inferred through an interpolation of countries' diversification (namely, the number of products that each country is connected to) and products' ubiquity (the number of countries that each product is connected to).

Secondly, the reason that a country's export basket includes a certain number (its degree of diversification) and types of products (its degree of technology complexity) is the result of its unique historical process of production-capabilities accumulation, structural change and production transformation within a certain global competitive context. Also the reasons that certain products are produced by relatively few countries (namely, are less ubiquitous) can be very different.

Sometimes products are less ubiquitous because their production requires very advanced technological capabilities whose accumulation requires long cycles of technological learning (e.g., precision engineering competencies, product system integration competencies, and competencies in combined technologies such as mechatronics applications). In other cases it might simply be that a certain country has managed to develop specific distinctive product qualities whose development is less capital intensive and more linked to local specificities (e.g., design in the case of furniture or variety and quality in the case of agricultural products such as coffee).

Thirdly, although depicting countries' product spaces informs policy makers about their 'products composition' (and the country's degree of export diversification), the 'method of reflections' approach does not tell us about the types of technological linkages of apparently related products. In other words, we have no information about the relationships of similarity and complementarity between production capabilities underpinning apparently related products. The fact that trade figures suggest a certain degree of relatedness is not sufficient for purposes of industrial policy design and might in fact be misleading.

Fourthly, given that the information about a country's capability is extracted from its 'expressed' export capacity--product composition and market performance--a number of 'potential' production capabilities for certain products may remain unnoticed. The fact that they are not reflected in the country's export figures may be simply because the international market demand for that product has been captured (and saturated) by other countries that managed to reach high economies of scale (e.g., China in a number of low- and medium-tech products).

Finally, in order to capture whether a country is (or is not) undergoing industrial learning and production-capabilities development processes, we need to wait until these dynamics are reflected in trade performance. Thus the snapshot offered by the product space might be affected by time lags. Learning processes proceed in historical time. Thus indicators that fail to consider the existence of time-lags will provide a very misleading picture of the capabilities that countries' production/technological structures (and the firms that compose them) possess.

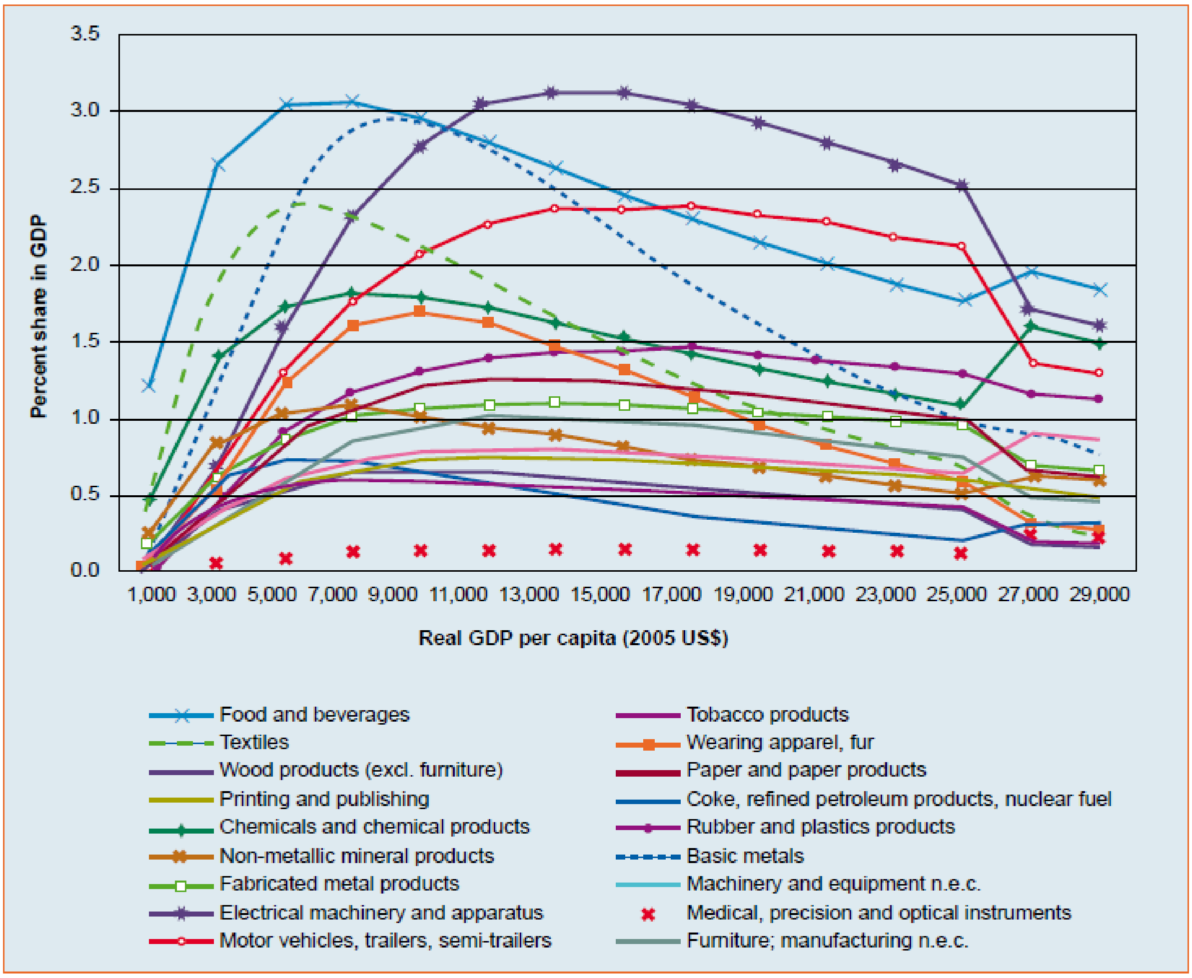
For example, consider a firm such as Nokia in its first years of high-tech production. A capability indicator based only on output variables would show us that Nokia is an incontrovertible story of continuous business failure since it did not make any profit in that business for almost two decades (Andreoni, 2011b). In sum, production capabilities development takes time and is cumulative so relying only on output variables will miss the ongoing learning process, which is not registered by the output-based indicator until a point further into the future.

The Growth Identification and Facilitation Approach

The GIF approach was recently proposed within the so-called new structural economics framework (Lin, 2012). In the words of its main architect, the former chief economist of the World Bank Justin Yifu Lin, the new structural economics (NSE) framework "advances a neoclassical approach to study the determinants and dynamics of economic structure. It postulates that the economic structure of an economy is endogenous to its factor endowment structure and that sustained economic development is driven by changes in factor endowments and continuous technological innovation" (Lin 2012: 5).

Although manufacturing development is recognised as an unavoidable step in the catching up process, a country's optimal industrial structure is derived from its comparative advantage, the latter being defined by factor endowments at each point in time. Specifically, the GIF codifies a six-step approach whereby countries start by identifying industries in which they have a latent-comparative advantage. In the following steps, countries are advised to deploy a number of tools to remove factors constraining their development. For the identification of these industries, the GIS proposes the following methodology: "the government in a developing country can identify the list of tradable goods and services that have been produced for about 20 years in dynamically growing countries with similar endowment structures and a per capita income that is about 100% higher than their own (Lin, 2012: 161).

Figure 2: Change in the share of manufacturing sub-sectors in GDP at selected per capita income levels for large countries



Source: Haraguchi and Rezonja, 2010; UNIDO 4digit Database.

The GIF approach is based on the implicit assumption that it is possible to identify a 'normal' pattern of structural change, provided that there is a certain degree of similarity in countries' endowment structure. The policy recommendation is that countries should aspire to the 'normal' production structure characterising countries with a per capita income that is 100% higher than their own[3] (see Figure 2).

While this approach seems to open what we might call a 'comparative advantage window', it is still fundamentally rooted in the idea that countries should not diverge significantly from adherence to comparative advantage. More critically, it does not recognise the possibility that countries might decide to combine comparative advantage-following strategies with comparative advantage-defying strategies beyond their normal pattern of structural change. A number of studies have provided evidence of the types of 'normal' structural- change patterns that countries should consider in their design of industrial policies (e.g., Alcorta, et al. 2014). However, the way in which these studies extract these 'normal' patterns of structural change presents a number of problems.

First of all, cross-sectional and time-series econometric studies covering a large number of countries for a period of 40 or 50 years and adopting a two-digit ISIC classification conflate in the same picture an enormous variety of countries' experiences and heterogeneous industrial sectors whose underpinning technologies and products characteristics have changed many times over time. Moreover, the adoption of per capita income as a proxy for the stage of economic development is very misleading. A country whose income per capita is inflated by a natural resources bonanza might have fewer production capabilities than another country with relatively lower income per capita. Notwithstanding, this methodology would suggest a broader 'comparative advantage window' for the 'less capable' country and, thus, more scope for production transformation.

Being able to extract an average or 'normal' pattern of structural transformation is certainly appealing. However, this approach misses the fact that successful industrial countries have often diverged from these patterns. In other words, they were 'a-normal' marginally, but in a persistent way over time. Secondly, the speed at which countries moved from one sector to another might change as a result of strategic choices that cannot be captured with 2-digit industry classifications. For example, Keun Lee (2013) shows how South Korea targeted

[3] Indeed the possibility of plotting 'normal' structural change patterns can be also found in the early work of Chenery (1960) and other structural economists.

those industries whose technology was characterised by short life cycles. As a result, South Korea managed to speed up the process of structural transformation.

Finally, not only are industrial sectors heterogeneous, they also change their nature over time. In other words, there are qualitative differences in the patterns of structural change followed by countries in the 1960s, 1970s, 1980s and so on. The production capabilities and technologies underpinning the same industry--for instance, the 'food and beverages' industry--in the 1960s would be completely different from those in the 2000s. While the data refer to the same sector (e.g., machine tools), over the years its nature has been changed (sometimes dramatically) by the introduction and integration of new technologies (such as mechatronics applications and control systems).

The production capability domains and the production structure composition

As mentioned above, production transformation is about learning and selective attempts to develop different capabilities in production (Andreoni, 2014). Firms' capabilities are personal and collective competencies, skills, productive knowledge and experiences needed for firms to perform different productive tasks, as well as to adapt and undertake in-house improvements across different technological and organizational functions.

From a 'static efficiency' point of view, *production and organisational capabilities* are *competencies, skills, productive knowledge and experiences* that agents and organisations require in order to choose, install and maintain capital goods, operate technical and organisational functions, and perform and monitor the execution of a set of interdependent productive tasks given certain time and scale constraints. Indeed, performing a set of interdependent productive tasks not only requires capable agents and functioning organisations--that is, individual and collective agents endowed with productive knowledge and relevant skills--but it also requires the establishment of a certain *production capacity*, that is, of *a scale-appropriate assortment of equipment, machinery and other capital goods*.

From a 'dynamic efficiency' perspective, the *absorption, adaptation and improvement of given productive techniques*, as well as *innovations across different organisational and technological* *functions*, depend mainly on the availability of other types of capabilities called *technological capabilities*. Moreover, capabilities needed to generate, absorb and manage technological and organizational change might differ substantially from those needed to operate existing production systems.

Firms operating in different sectors (or in the same sector but in different country contexts) develop different capabilities in production. Even when these capabilities are similar, they are combined and deployed in different ways in order to run different production processes and obtain products with different characteristics and quality standards. Moreover, changes in processes and product upgrading always require a process of learning whereby existing competencies are recombined or new ones are introduced and integrated within the existing production structures.

Thus, learning and capabilities development in production are the result of purposeful processes of trial and error, reverse engineering and technological absorption, re-engineering and adaptation, and scaling-up and diversification. These processes are costly and risky, especially when firms attempt to capture value opportunities in complex product systems--that is, by producing products composed of multiple sub-components whose integration requires accumulated capabilities. Therefore, new production opportunities are not simply 'self-discovered'; they are continuously searched for and constructed within (and between) production organisations in specific historical contexts.

A strategic, but also pragmatic, approach to production transformation starts from the recognition of the centrality of these learning dynamics, and their sectorial and contextual specificity, as well as an awareness of the related challenges and risks of failure. In order to reduce some of these risks and challenges, governments can adopt different types of selective strategies.

Traditionally, governments have targeted specific sectors and created a market for their development. While this sectorial approach is often necessary at initial stages of industrialisation, an effective way to diversify a country's production structure is to start focusing on cross-sectorial interventions that target specific technological linkages and potential processes of inter-sectorial learning (Andreoni, 2014).

Within a selective industrial policy approach that targets cross-sectorial dynamics, governments focus on a limited number of *capability domains*, such as capabilities in food processing, capabilities in advanced materials, capabilities for mechanics and control systems, ICT capabilities or capabilities in production technologies. Each one of these capability domains constitutes a platform of competencies, technologies, productive knowledge and experiences that can be deployed in a plurality of sectors. For example, the agro-food sector might draw on a combination of food processing capabilities, but also capabilities for mechanics and control systems for food packaging, ICT capabilities for food tracking and, finally, capabilities in advanced materials for smart packaging.

By nurturing the development of complementary sets of capabilities (each a part of closely related capability domains), the scope for technological innovation within and across sectors tends to increase and new development trajectories are potentially built. Of course, the initial investment in certain production capability domains (instead of others) is path dependent and context specific. Countries' production capabilities accumulate over time and tend to concentrate in specific locations. Therefore, while governments should select the capability domains to develop (in partnership with the private sector and according to its political vision), industrial policy strategies should always be accompanied by a country-specific mapping of inherited production capabilities and existing structures.

Sectorial and cross-sectorial policies are costly and learning dynamics take time. In order to pay the bill of production transformation, existing sectorial strengths in broadly defined low-tech sectors should not be undermined. In their initial stages of industrialisation, developing countries' production structure (and, thus, their export basket) is mainly based on agricultural activities and products. In this context, Arthur Lewis (1958: 433) noted how "it is not profitable to produce a growing volume of manufactures unless agricultural production is growing simultaneously. This is also why industrial and agrarian revolutions always go together, and why economies in which agriculture remains stagnant do not show industrial development".

This sustainability problem (i.e., guaranteeing a sustained level of agricultural output) is especially critical in the early phases of development when manufacturing growth is still strongly dependent on the agricultural sector for surplus labour, savings, and inputs for industrial processing and demand for manufactured goods. At more advanced stages of industrialisation, the manufacturing sector tends to 'self-reproduce' while the inter-sectorial transfer of resources from agriculture to other sectors tends to be balanced and eventually reversed.

Writing about this same sustainability problem, Kuznets (1968) observed how a self-sustained process of structural change requires technological advancement and thus increasing productivity in agriculture *as well as* in industry. In his view the shifting of the productive structure towards manufacturing and the redistribution of employment from agriculture to industry are consequences rather than causes of industrialisation, occurring because of technological change in the industrialising economy. This vision illustrates how increasing productivity in the agricultural sector arises from 'manufacturing agrarian change' Andreoni, 2011), that is, through the adoption/adaptation/application to the agricultural sector of those technological innovations that were developed intra- or inter-sectorally[4].

For this reason, consideration of how much and for how long agriculture can support industrialisation has to be complemented by considerations of how much and in which ways industrialisation can 'technologically push' agrarian change. This observation directs our attention to the identification of a *technological interdependence* existing between agriculture and manufacturing, a relationship that can also be extended to services (Hirschman, 1958). This technological interdependence refers to the transformative power that an increasingly technologically advanced manufacturing sector can have with respect to the agrarian sector (as well as other sectors).

These intersectoral linkages are destined to change and "vary according to the particular phase of the development process and as structural conditions and international circumstances change" (Kay, 2009: 116). For example, it has been observed how, with the increase of productivity in agriculture, backward linkages between agriculture and services have been expanding in both magnitude and quality. Good examples include post-harvest

[4] The importance of technological advances in agriculture was also stressed by Kalecki (1976), who dedicated much attention to the existence of bottlenecks in the agricultural sector.

facilities such as transport, communication, information services for production control in agriculture and marketing services.

Historically, industrialising countries have nurtured these sectoral and intersectoral dynamics by promoting import substitution (IS) and export promotion (EP) strategies. While these policies have been traditionally presented in contraposition, Hirschman (1968) has stressed how in fact they have been used in combination by the same countries. More recently, Chang (2009) has highlighted how "…in East Asia, free trade, export promotion (which is, of course, not free trade), and infant industry protection were organically integrated, both in cross-section terms (so there always will be some industries subject to each category of policy, sometimes more than one at the same time) and over time (so, the same industry may be subject to more than one of the three over time)". IS and EP strategies may have a mutually reinforcing effect on the production structure and can be used in different combinations at different stages of development and with different objectives[5].

The production transformation functions of intermediate institutions

Industrial learning requires specific ingredients and collective efforts, especially in the transition from an agricultural to an industrial economy. 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 become critical. These processes tend to be facilitated and triggered by intermediate

[5] See Andreoni, 2015b for a comparative analysis of industrial policy packages in major industrialised and industrialising economies.

institutions such as agrarian research institutes, technology centres, extension services, quality certification and standards providers (Andreoni and Chang, 2014).

Historically, intermediate institutions have taken different 'forms' and have performed different combinations of 'production functions'. These institutions are called intermediate since they play a critical intermediary role between R&D, education, markets and on-farm agricultural production. They also bridge and transfer knowledge, technical solutions and innovations across different sectors and, thus, facilitate various forms of inter-sectoral learning (Andreoni, 2011).

The transformation of the agricultural sector can be facilitated and triggered by designing a whole range of intermediate institutions and organizations for the provision of innovative 'extension, production and technology services'. Traditionally, extension services aimed to 'translate' technological innovations originating in the manufacturing sector into use in agriculture. Moreover, they were meant to provide assistance to farmers—for example, in repairing new mechanical tools or in the utilization of chemical fertilizers. The idea of 'itinerant instructors' and, more generally, extension services was successfully adopted in particular by Germany, Denmark and Sweden in Europe, but also in the US and Japan. Interestingly, these are among the countries that experienced the highest increase in gross output and total productivity rates during the years of the first green revolution (Andreoni and Chang, 2014).

Innovative extension, production and technology services may not only facilitate the application of new technologies, but also proactively involve farmers in the design, experimentation and improvements of new technologies. Since these activities imply farmers' direct involvement in processes of trials and errors, inverse engineering and the redesign of 'crop-growing techniques', they would result in a sustained process of on-farm technological-capabilities building. In particular, given the increasing complexity of technologies adopted in agriculture, small and medium farmers are particularly in need of mastering technological innovations. Evidently, given the high costs of these activities and the 'public character' of some of them, there is a strong rationale in favour of public intervention.

Two successful cases of intermediate institutions--Fundación Chile and Embrapa in Brazil--may help in highlighting their specific functions and cross-sectoral development impact (Andreoni and Chang, 2014).

Brazil

Over the last thirty years Brazil has been among the most active countries in terms of their use of policies designed to expand natural-resource-processing industries and food production. The results of these transformative policies are reflected in the remarkable results that Brazil have achieved in manufacturing its agrarian change. Brazil is today among the top three producers and exporters of orange juice, sugar, coffee, soy beans, beef, pork and chickens as well as having caught up with the traditional big five grain exporters (US, Canada, Australia, Argentina and the European Union). At the centre of the transformative policy package implemented in Brazil, there is a network of intermediate institutes--e.g., Embrapa, which have fostered technological change, diversification and upgrading in agriculture and farming.

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 Brazil's national agricultural research agency. Brazil is a country with one of the most well-developed and well-funded agricultural 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 a large number of agricultural universities (around 80). There are also a large number of agricultural research centres, some of which have been in existence since the early 19th century. This arrangement makes the current Brazilian agricultural research system extremely complex and characterised by overlapping networks (e.g., 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 by staff and budget the largest R&D agency of any kind, not just in agriculture, in Latin America. 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.

Chile

During 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 tomatoes. Interestingly, at the centre of the transformative policy package implemented in Chile there was another model of intermediate institutes for agricultural transformation.

Fundación Chile (FCh) is a non-profit semi-public institution created by Decree 1528 issued on August 3, 1976 and 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 has 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, 2005, p. 3).

To sum up on the basis of the above examples, intermediate institutions play a pivotal role in developing countries' national system of innovations. More specifically, their production functions include:

- The identification, adaptation and development of agro-technologies through feasibility studies and market opportunity scouting, experimental testing, demonstration projects, lab testing, quality certification and product/process control;
- The diffusion and transfer of these technologies through technical assistance, demonstration projects, quality certification and product/process control, extension services, and the piloting of innovative companies in partnership with private companies;

- The nurturing of focal technological linkages across sectors, especially with manufacturing, as many of the agro-technological innovations have come from manufacturing industries.

Concluding remarks

Over recent years the Ethiopian economy has made important efforts towards production transformation. For example, a number of intermediate institutions, such as LIDI and LLPTI for the leather industry or the EHDA in the floriculture industry, have been developed and have supported important sectors of the economy.

Moving beyond ungrounded approaches to production transformation based mainly on output figures, this paper has stressed the importance of refocusing on in-firm learning processes and, as well, the opportunity of developing production capability domains underpinning closely complementary sectors and activities.

Within the strategic and pragmatic approach to industrial policy envisioned here, the important role that traditional sectors such as agriculture can play in industrialisation is emphasised. In the case of Ethiopia these sectors and products account for a significant part of the economy, with the coffee production sector alone representing almost 30% of the country’s export basket.

Finally, the functioning of intermediate institutions in Ethiopia could be improved by learning from international experiences, such as those of Embrapa and Fundación Chile. Indeed, while these intermediate institutions might take different forms, they tend to perform a similar set of production transformation functions.

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